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14. ABSTRACT
This TOP provides procedures to characterize an ambient radio frequency (RF) environment (sometimes referred to as "radio frequency noise") prior to testing of a specific system under test (SUT). With this characterization, locations can be selected to avoid RF interference, providing optimal test conditions for the given SUT. This procedure requires calibrated equipment to generate accurate results, allowing for comparisons between test locations, and selection of the best location for a given test.

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U.S. ARMY TEST AND EVALUATION COMMAND
TEST OPERATIONS PROCEDURE

*Test Operations Procedure 06-2-595 — 16 February 2016
DTIC AD No.

CHARACTERIZATION OF AN OUTDOOR AMBIENT RADIO FREQUENCY ENVIRONMENT

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1. SCOPE.

Testing radio frequency (RF) systems requires measurement and characterization of the ambient RF environment at proposed test locations. This characterization is essential to adequately plan, operate, and fairly test RF systems.

1.1 Purpose.

a. This Test Operations Procedure (TOP) is focused on the characterization of an ambient RF environment (sometimes referred to as "radio frequency noise") prior to testing of a specific system under test (SUT). With this characterization, locations can be selected to avoid RF interference, providing optimal test conditions for the given SUT. This TOP provides guidance for measuring and characterizing the RF environment in urban and rural environments in the 2-megahertz (MHz) to 6-gigahertz (GHz) frequency range; it is easily expandable to include higher frequencies, as required. This procedure requires calibrated equipment to generate accurate results, allowing for comparisons between test locations, and selection of the best location for a given test. The method should be simple and should be designed to use available equipment such as the spectrum analyzer commonly used at test facilities. This TOP assumes that someone with a basic understanding of RF, and who is skilled to operate a spectrum analyzer, will make these measurements.

b. This TOP incorporates Military Standard (MIL-STD)-461F[1**] (the Department of Defense (DOD) standard for electromagnetic interference (EMI) measurements in an anechoic (i.e., non-echoing) chamber), and CISPR 16[2] (the European standard for open-air measurement of EMI). CISPR stands for "Comité International Spécial des Perturbations Radioélectriques", or in English, "International Special Committee on Radio Interference". Because the interest in this TOP is to achieve measurements at the lowest displayed average noise level (DANL), modifications to these two standards will both increase sensitivity and integrate existing spectrum analyzers.

c. This TOP specifies use of spectrum analyzers because they are more readily available than are EMI receivers. The technician operating the spectrum analyzer and making the measurements should verify that the equipment is calibrated and is functioning properly and accurately. Appendix A provides the mathematical processes used to calculate the operating parameters to verify that the equipment is functioning properly and that the obtained measurements are accurate. The mathematical formulas listed were obtained from standard reference books on RF theory. The formulas are formatted in a style to be easily incorporated into a spreadsheet.

1.2 Terms and Conditions.

This document establishes comprehensive procedures for characterizing the ambient RF environment at a specific location. Based upon these initial measurements, the test officer may tailor or expand these procedures to optimize the scenario and test resources in the specific RF bands tested.

** Superscript numbers correspond to Appendix C, References.

1.3 Limitations.

a. Radio spectrum certification and radio frequency authorization (RFA) (spectrum use approval) are required for all RF transmissions in open-air testing. Where certifications and approvals are not available, testing must be restricted to a closed-loop laboratory or an isolated anechoic chamber environment. Although this TOP addresses only the characterization of the ambient RF environment, care should be taken to ensure compliance with all applicable policies and regulations regarding the transmission of RF energy.

b. As stated in paragraph 1.1.a, this TOP addresses only those RF frequencies in the 2-MHz to 6-GHz frequency range. Expansion to other frequencies will require additional hardware, with calibration tables, to complete the measurements.

2. FACILITIES AND INSTRUMENTATION.

2.1 Facilities.

In general, RF systems are initially tested in an anechoic chamber, with low ambient RF energy present. These systems transition to open-air facilities to verify operation under real-world conditions. This TOP is specific for open-air facilities and ranges, and it covers both "parking lot" tests and field tests, described as follows:

a. "Parking lot" tests occur outdoors within a small physical area, usually (but not always) a parking lot. The area should be fenced and access-controlled.

b. Field tests introduce operational realism into the test scenarios. Field tests at test ranges are typically spread over many square miles. Using this TOP, measurement of the ambient RF environment at several locations within the test area is recommended to adequately understand the test conditions.

2.2 Instrumentation.

This TOP requires the use of a spectrum analyzer, antennas, cables, and other RF equipment. The specific equipment used in the development of this TOP is as follows, but substituting the RF equipment with other high quality calibrated equipment will yield satisfactory results:

a. Spectrum Analyzer: Agilent E4407B***.

b. Antenna: A.H. Systems, Inc., EHA-51B antenna with rod for 2 - 30 MHz.

c. Antenna: MP antenna 08-ANT-0861 for 30 MHz - 6 GHz.

d. Preamplifier: Mini Circuits ZVA-213-S+ for 800 MHz - 21 GHz.

*** The use of brand names does not constitute endorsement by the Army or any other agency of the Federal Government, nor does it imply that it is best suited for its intended application.

e. Preamplifier: Mini Circuits ZFL-1000LN+ for 0.1 - 1000 MHz.

f. Bias Tee: Mini Circuits ZFBT-6GW-FT+.

g. RF cables and connectors.

h. Computer: Dell Latitude E6410 with Microsoft Office.

3. TEST PROCEDURES.

3.1 General.

a. Appendix A provides a detailed discussion of RF theory and also provides measurement information. The calculations presented in the Appendix will predict the results of the measurements and provide a “sanity check” of the measured results.

b. The test procedures use two configurations: the first covers the 2-MHz to 30-MHz frequency range, and the second covers the 30-MHz to 6-GHz frequency range. Antenna characteristics dictate the division of the bands. The measurement of frequency bands in this procedure must agree with the antenna characteristics and calibration tables.

c. Antenna placement is critical for the measurements. All antennas will be placed in the open, away from structures, power lines, or any other equipment that would generate noise. For the lowest frequency band, a vertical element approximately 1 meter tall is connected to an amplifier at its base and makes up the complete antenna. The amplifier acts as an impedance converter, changing the high impedance of the rod to a low impedance capable of driving the coax cable. The coax cable would act as a dead short connected directly to the high impedance of a short antenna, thus shorting the signal to ground. The impedance converter takes care of this problem. This type of antenna is universally used for reception at low frequencies.

3.2 2-Megahertz (MHz) to 6-Gigahertz (GHz) Characterization.

Figures 1 and 2 show, respectively, the configurations that cover the 2-MHz to 30-MHz and 30-MHz to 6-GHz frequency bands.

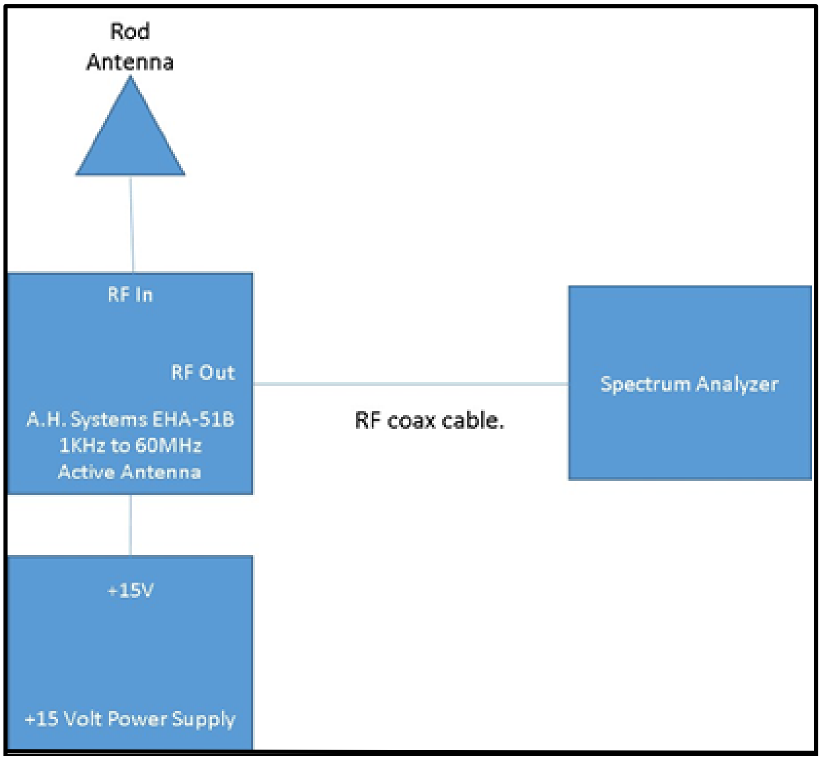

Figure 1. Ambient noise measurement equipment configuration, 2 - 30 MHz.

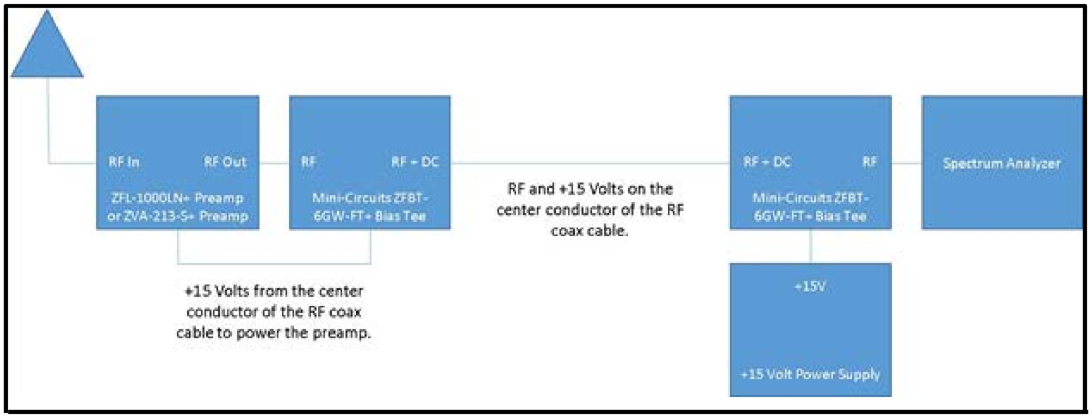

Figure 2. Ambient noise measurement equipment configuration, 30 MHz - 6 GHz.

3.3 <u>Equipment Setup</u>.

a. Table 1 defines the settings for the spectrum analyzer to provide consistency for ambient measurements.

TABLE 1. SPECTRUM ANALYZER SETTINGS

Frequency Band:	2 - 30 MHz	30 - 200 MHz	200 MHz - 1 GHz	1 - 2 GHz	2 - GHz
Reference Level:	-30 dBm	-30 dBm	-30 dBm	-30 dBm	-40 dBm
Attenuation:	0 dB	0 dB	0 dB	0 dB	0 dB
Internal Preamplifier:	Off	Off	Off	Off	Off
Start Frequency:	2 MHz	30 MHz	200 MHz	1 GHz	2 GHz
Stop Frequency:	30 MHz	200 MHz	1 GHz	2 GHz	6 GHz
Resolution Bandwidth:	10 kHz	100 kHz	100 kHz	1 MHz	1 MHz
Video Bandwidth:	30 kHz	300 kHz	300 kHz	3 MHz	3 MHz
Detector:	Manual, Peak	Manual, Peak	Manual, Peak	Manual, Peak	Manual, Peak
Sweep Time:	2.8 seconds	0.17 seconds	0.8 seconds	0.01 seconds	0.04 seconds
Trace Average:	100 traces	100 traces	100 traces	100 traces	100 traces
dB - decibel; dBm - decibels referenced to 1 milliwatt; kHz - kilohertz					

b. An A.H. Systems, Inc., EHA-51B antenna with a rod element instead of a loop (Figure 3) is used to measure the 2-MHz to 30-MHz band. The calibration sheet that comes with the antenna includes the antenna factor and isotropic gain in decibels referenced to an isotropic antenna (dBi). The gain using the dipole antenna as a reference was calculated by subtracting 2.15 dB from the isotropic gain. Table 2 provides a partial listing, containing only the frequencies that were used. The data in the “Gain dBd” column are entered into the spectrum analyzer correction table. Only the values from 2 to 30 MHz need to be entered; entering all of the antenna’s frequencies is not necessary.

Figure 3. Antenna with rod erected in an open field.

TABLE 2. EXCERPT FROM ANTENNA CALIBRATION TABLE

FREQUENCY (MHz)	Antenna Factor (AF) (dB/m)	GAIN	
		dBi	dBd
2	4.65	-28.40	-30.55
3	4.53	-24.76	-26.91
4	4.52	-22.25	-24.40
5	4.48	-20.27	-22.42
6	4.45	-18.66	-20.81
7	4.42	-17.29	-19.44
8	4.44	-16.15	-18.30
9	4.43	-15.12	-17.27
10	4.40	-14.17	-16.32
15	4.39	-10.64	-12.79
20	4.08	-7.83	-9.98
25	4.09	-5.90	-8.05
30	4.17	-4.40	-6.55

c. In Table 2, the gain of the antenna varies from -30.55 decibels referenced to a dipole antenna (dBd) at 2 MHz, to -6.55 dBd at 30 MHz, a change of 24 dB. This is typical for this type of antenna as well as many of the higher frequency wideband antennas. If these correction gain figures, based on antenna factor (AF) in dB/m, were not entered into the spectrum analyzer correction table, the baseline on the display would have a 24-dB slope and an accuracy of ±12 dB. This, in addition to the ±2 dB allowed for the spectrum analyzer, could cause a total possible error of ±14 dB. As shown, the correction tables must be used if enough accuracy is expected for comparisons between areas to be made. Below 30 MHz, the loss in the coax cable is so low as to be insignificant; the base of the antenna is 1 meter above the ground.

d. As shown in the 2-MHz to 30-MHz ambient scan (Figure 4), the measurement is an average of 100 sweeps. The DANL for this scan is established by the noise figure of the EHA-51B active antenna, not the spectrum analyzer. To further reduce the DANL, a lower noise active antenna can be used. In this case, several ambient signals are shown as spikes above the noise floor of the spectrum analyzer. Using this information and the specific RF frequencies of the device to be tested, appropriate frequencies (e.g., ones without an ambient RF interference source) should be used. If the device to be tested does not have the capability to adjust frequency, and if there is an ambient RF interference source, other locations should be analyzed in order to select ones with minimum RF interference. It may not be possible to select a location with no RF interference sources.

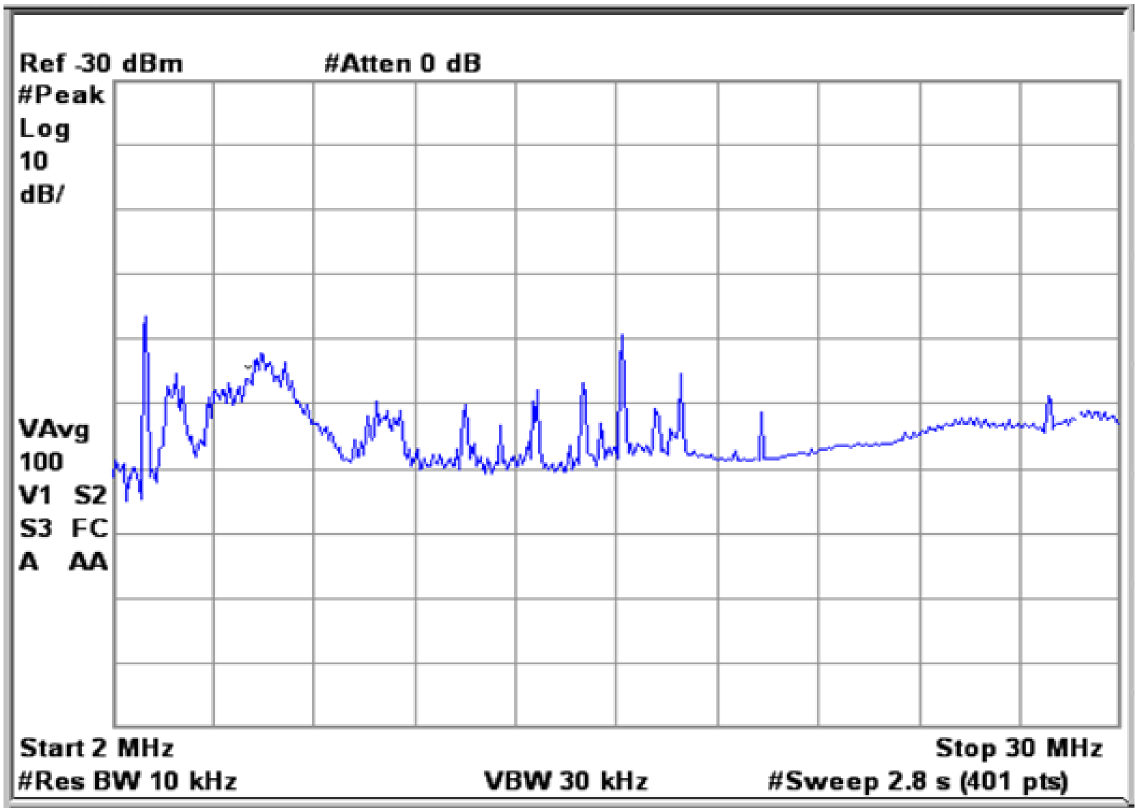

Figure 4. Ambient scan, 2 - 30 MHz.

e. To measure the 30-MHz to 6-GHz band, the band will have to be subdivided by frequency to achieve a reasonable resolution on the spectrum analyzer; in this case, 30 - 200 MHz, 200 MHz - 1 GHz, 1 - 2 GHz, and 2 - 6 GHz.

f. To improve measurement accuracy, a preamplifier should be used (see Appendix A for details). The characteristics of this preamplifier, as well as those of all other equipment, must be included in the calibration tables. Figure 5 shows the MP antenna 08-ANT-0861, which was used for scans from 30 MHz to 6 GHz. The bias tee in Figure 6 removes the +15 volts from the center conductor of the coax connecting it to an external pin and isolates the output of the preamplifier from direct current (dc). The red wire connects that pin to the power supply input pin on the preamplifier, as shown in Figure 7. The preamplifier and bias tee configuration shown in Figure 7 is mounted at the output port of the antenna for the 30-MHz to 1-GHz spectrum scans. The center conductor of the coax cable is used to power the preamplifier mounted at the base of the antenna. The bias tee also isolates the input port of the spectrum analyzer. If bias tees are unavailable, a separate external wire would be used to power the preamplifier. Figure 8 shows how the bias tee is used to insert 15 volts onto the center conductor of the coax powering the low noise amplifier at the base of the antenna.

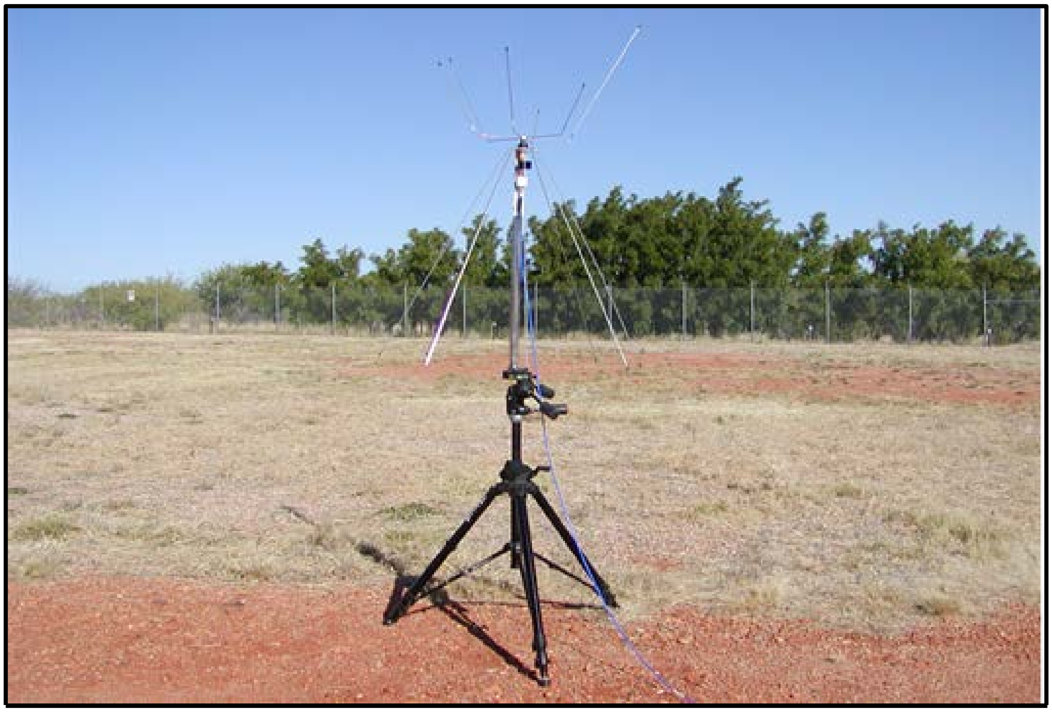

Figure 5. MP Antenna 08-ANT-0861.

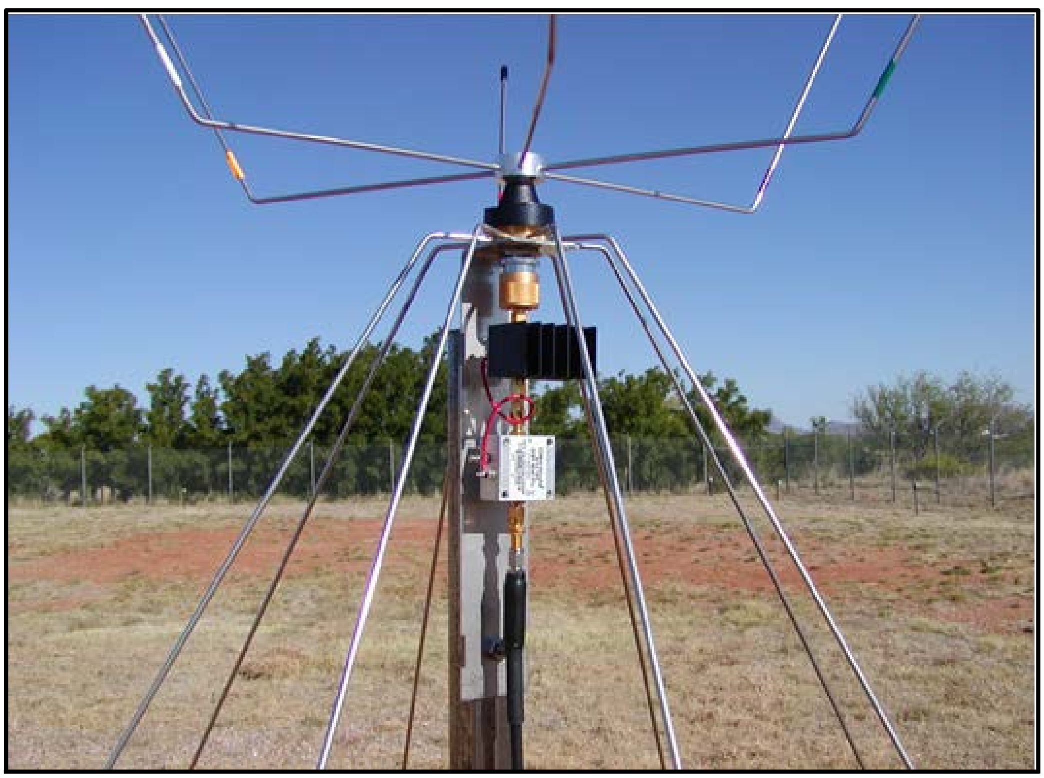

Figure 6. Close-up of the mini circuits ZVA-213-S+ preamplifier connected to the antenna output port and the mini circuits ZFBT-6GW-FT+ bias tee mounted underneath.

Figure 7. Close-up of the mini circuits ZFL-1000LN+ preamplifier connected to the mini circuits ZFBT-6GW-FT+ bias tee.

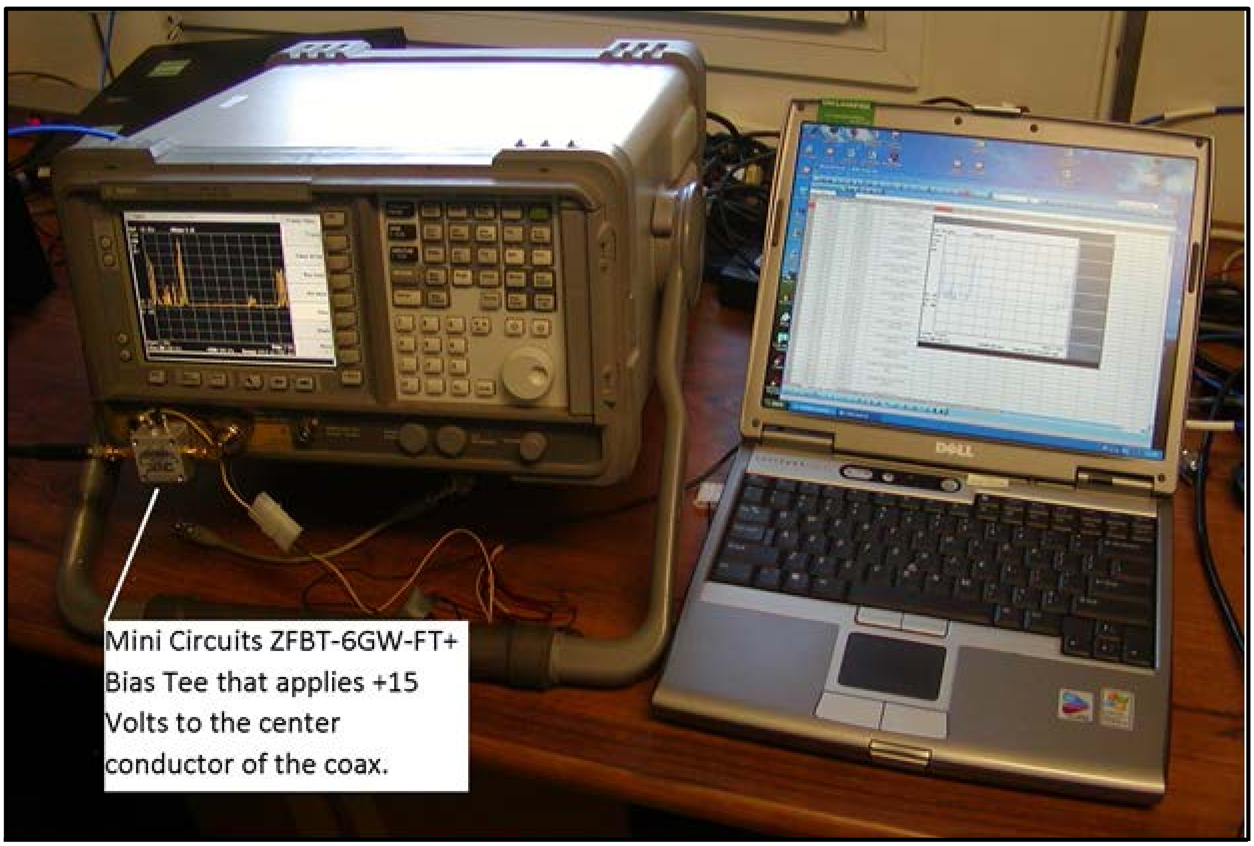

Figure 8. Spectrum analyzer and laptop computer for recording ambient noise spectrum scans.

g. The 08-ANT-0861 antenna gain correction table (Table 3) is used for the remainder of the ambient scans from 30 MHz to 6 GHz. Table 4 lists the gain corrections for the Mini Circuits ZVA-213-S+ preamplifier combined with the loss contributed by the 20-foot test cable. The Mini Circuits ZVL-1000LN+ amplifier gain table (Table 5) used for the two ambient scans from 30 MHz to 1 GHz is a combination of cable loss subtracted from amplifier gain.

TABLE 3. 08-ANT-0861 ANTENNA GAIN CORRECTION

FREQUENCY (MHz)	GAIN	
	dBi	dBd
25	1	1.15
60	2.5	0.35
110	4	1.85
210	3.2	1.05
300	3.4	1.25
500	3.5	1.35
700	2.8	0.65
900	3.3	1.15
1000	3	0.85
1100	2.8	0.65
1200	2.5	0.35
1300	2.8	0.65
2000	2.8	0.65
2100	3	0.85
2400	2.2	0.05
2700	2	0.15
3300	3.5	1.35
3800	3.5	1.35
4300	2.6	0.45
4700	2.6	0.45
5000	2.9	0.75
5300	2.6	0.45
5600	2.6	0.45
5700	2.7	0.55
6000	2.7	0.55

TABLE 4. MINI CIRCUITS ZVA-213-S+ AMPLIFIER GAIN COMBINED WITH 20-FOOT TEST CABLE LOSS

GHz	GAIN (dB)
1.00	22.00
1.50	21.80
2.00	21.70
2.50	20.90
3.00	20.10
3.50	19.20
4.00	18.60
4.50	18.20
5.00	17.60
5.50	16.90
6.00	16.80

TABLE 5. MINI CIRCUITS ZVL-1000LN+ AMPLIFIER GAIN COMBINED WITH 20-FOOT TEST CABLE LOSS

MHz	GAIN (dB)
30	22.1
50	21.9
100	21.5
200	20.9
300	21.1
400	21.2
500	20.9
600	20.8
700	20.5
800	20.5
900	20.1
1000	19.5

h. Figures 9 through 12 provide scans of the ambient RF environment.

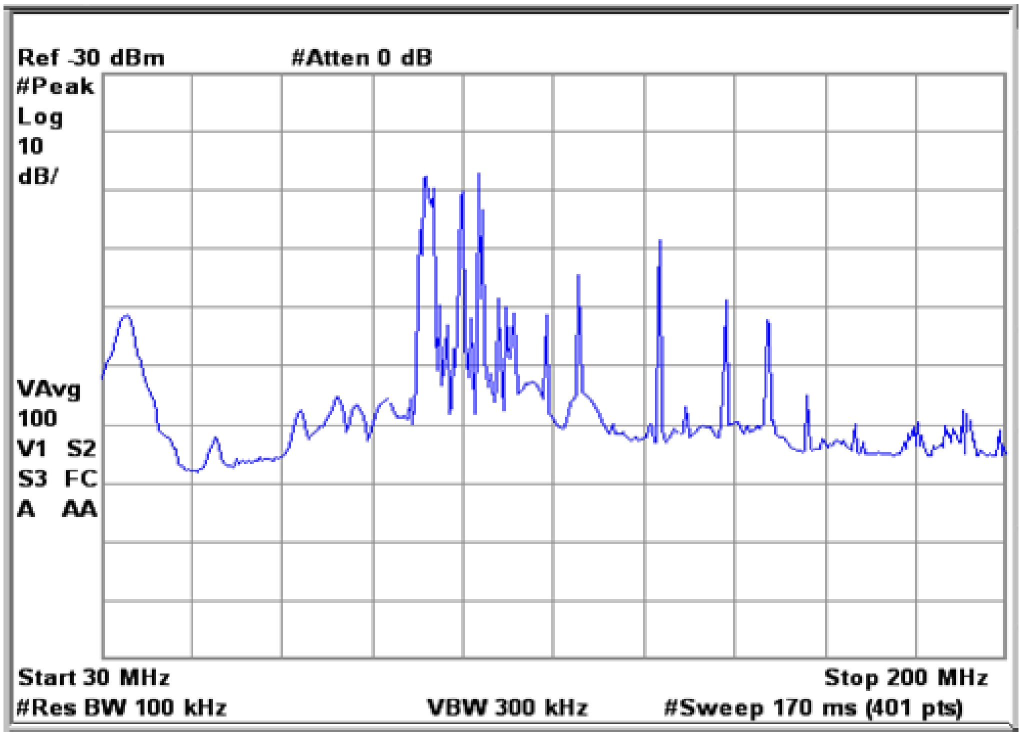

Figure 9. Ambient scan, 30 - 200 MHz.

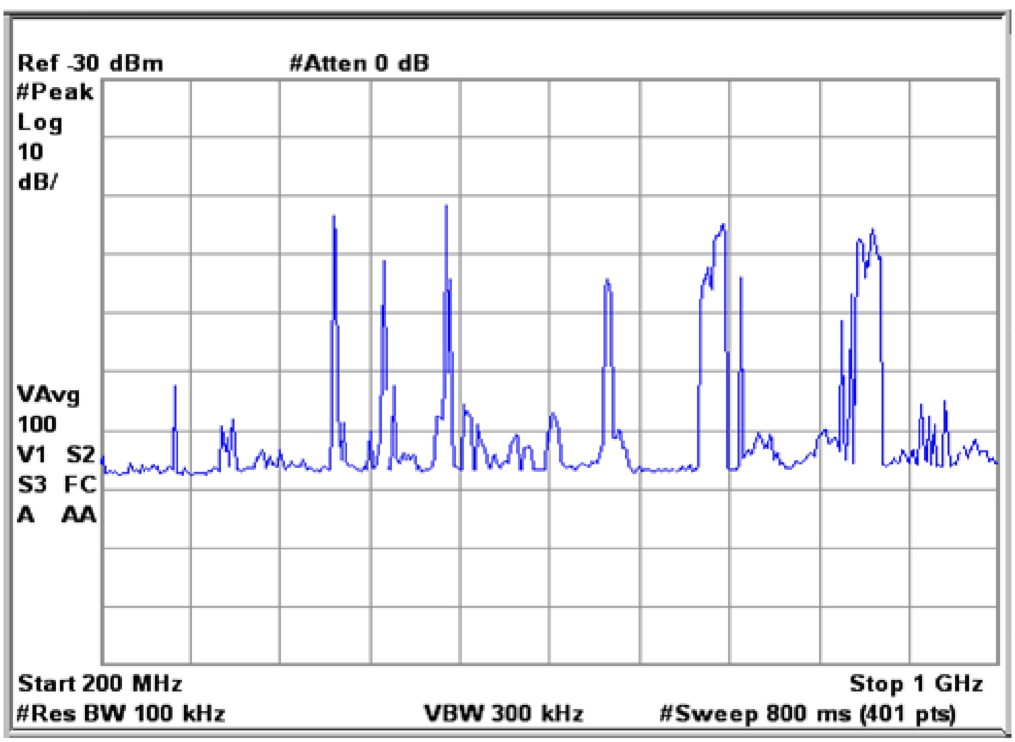

Figure 10. Ambient scan, 200 MHz - 1 GHz.

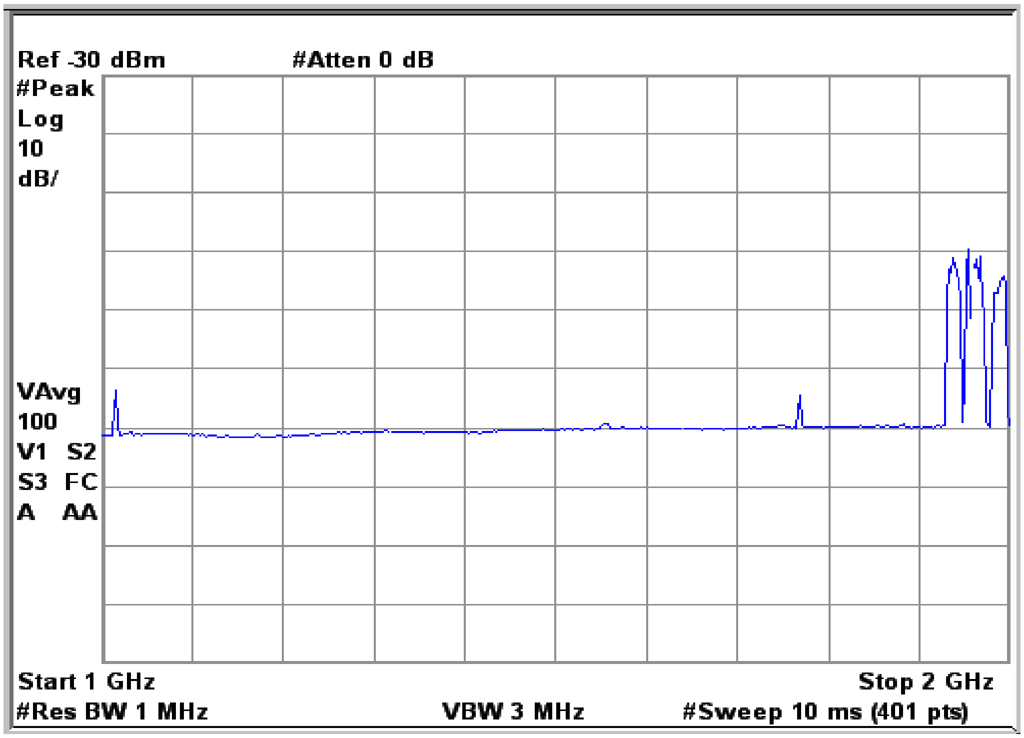

Figure 11. Ambient scan, 1 - 2 GHz.

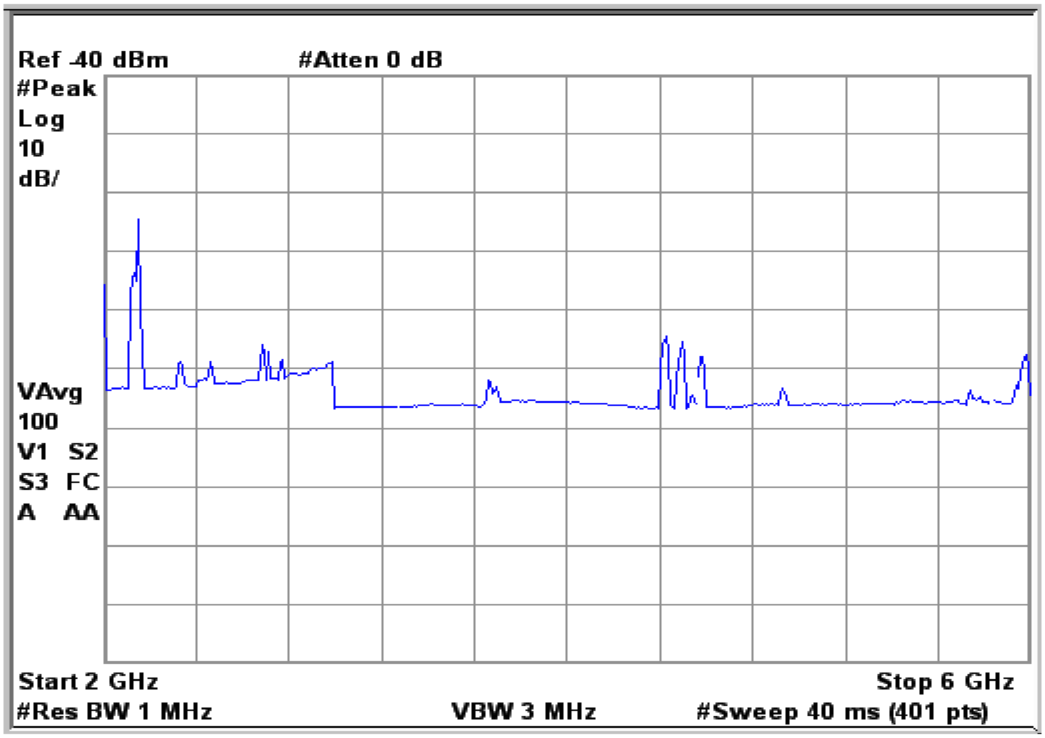

Figure 12. Ambient scan, 2 - 6 GHz.

4. CONCLUSION.

The procedures described in this TOP characterize the RF environment in preparation either for an outdoor test or for the comparison of two or more locations of interest. Although useful in identifying ambient RF interference, this method should be used in conjunction with other tools as needed. These procedures provide an outline and a place to start, along with methods to increase the sensitivity of the measurements. When planning specific RF testing, focus on narrower frequency bands should be examined in much greater detail by reducing resolution bandwidth (RBW) to look lower in the noise floor of the instrument. Instruments capable of fast Fourier transform (FFT) can be used where only relative instead of calibrated measurements are required. Vertical polarization was primarily used in this TOP because it enables omnidirectional reception. Horizontal polarization with log periodic or other directional antennas may be used if the device to be tested employs that RF characteristic. These measurements can extend above 6 GHz and below 2 MHz, limited only by the response of the equipment used.

5. DATA REQUIRED.

Data required is dependent upon the requirements of each test. All requirements and data needs should be discussed and approved by the U.S. Army Test and Evaluation Command (ATEC) Systems Team (AST) and the customer.

6. PRESENTATION OF DATA.

Data should be presented in formats that best fit the needs of the AST and customer. Samples of data plots are included as Figures 9 through 12.

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APPENDIX A. BACKGROUND INFORMATION.

A.1 GENERAL.

Appendix A provides a discussion of the theory used in this TOP. Using the information in this Appendix, prediction of the expected measurement results can be compared to actual measurements. The comparison provides a check for reasonability of the measured results.

A.2 ABSOLUTE NOISE FLOOR VS. INTERFERENCE LEVEL.

a. The noise floor of the measurement device is the limiting factor with any RF measurement. The noise floor is the measure of all noise sources and unintentional signals within the measurement system. The ambient noise floor anywhere cannot be measured, but it can be calculated knowing the temperature and RF bandwidth. The RF bandwidth for this calculation is assumed to be 1 hertz (Hz). The ambient noise floor is -174 decibels referenced to 1 milliwatt (dBm) at 290 °K (temperature in Kelvin) or room temperature at 1-Hz resolution bandwidth (RBW). The ambient noise represented by “kTB” is Boltzmann’s Constant (1.380 x 10-23 J/K) times the temperature in Kelvin times the bandwidth in Hz, resulting in decibels referenced to 1 watt (dBW), then converted to dBm referenced to 1 milliwatt.

$$1.380 \times 10^{-23}\ \text{J/K} \times 290\ °\text{K} \times 1\ \text{Hz} = 3.98\text{E-}21 \qquad \text{Equation 1}$$

To get the results in power (dBW), the formula becomes:

$$10\text{Log}_{10}\ (\text{kTB})\ \text{which is -204 dBW} \qquad \text{Equation 2}$$

This is then converted to dBm by adding 30 dBm:

$$-204\ \text{dBm} + 30\ \text{dBm} = -174\ \text{dBm} \qquad \text{Equation 3}$$

b. “KTB” cannot be measured because any instrument being used has a noise figure that is added to -174 dBm. The measurement becomes the baseline noise of the instrument and not that of the surroundings.

c. Because the ambient noise level anywhere can be calculated knowing the temperature and bandwidth, the real question becomes “what is the level of unwanted emissions in a specific test area?” With that question, certain parameters, such as frequencies of interest, bandwidth of modulated signals, whether the interference is constant or periodic, and level of propagation of distant signals, must be known. Propagation of distant signals depends on additional conditions such as solar flux and time of day. As can be seen, precisely measuring the level of interference anywhere is complicated.

APPENDIX A. BACKGROUND INFORMATION.

A.3 MEASUREMENT ACCURACY AND CALIBRATION.

a. Calibrated equipment, either a spectrum analyzer or EMI receiver operated in the spectrum analyzer mode, must be used. Calibrated antennas having correction factors, high-quality coax cables, and low-noise preamplifiers for the frequencies of interest, will be needed. If the result of the measurements is to compare the level of interference and noise in two or more locations, then the signals being measured are “far field” instead of “near field”. In electromagnetic compatibility (EMC) testing in anechoic chambers, the antennas have calibration tables in frequency steps corresponding to antenna factors in dB that result in voltage for a specific distance away from the equipment under test (EUT). The calibration tables may also include isotropic gain in decibels referenced to an isotropic antenna (dBi). The distance is usually 1 meter and the units of measure are decibels referenced to 1 microvolt per meter (dBµV/m). In the case of far field measurements, the antenna factors need to be converted to gain figures in decibels referenced to a dipole antenna (dBd). The unit of measure is in power over 1 milliwatt or dBm. If the calibration tables include gain, it will be in dBi, which will then need to be converted to dBd. The formula to convert the antenna factor to dBi is:

$$Ga = 10 \log \left[2.4 \left[\frac{2\pi}{\lambda \; 10^{(Af/20)}} \right]^2 \right] \qquad \text{Equation 4}$$

b. The antenna factor “Af” shown in the formula is for frequency; therefore, the frequency needs to be converted to wavelength “λ” by dividing the speed of light in milliseconds (ms) by the wavelength in meters, 300/f [MHz]. A column of numbers may need to be converted. The spreadsheet formula is:

Gain in dBi =10×LOG10(2.4× (2×PI()/((299.792458/frequency in MHz)×10^(antenna factor/20)))^2) Equation 5

c. The isotropic gain in dBi, either from the formula or already listed, is then converted to gain referenced to a dipole antenna in dBd by subtracting 2.15 dB. The spreadsheet formula is:

Gain in dBd = gain in dBi - 2.15 Equation 6

d. Loss in the coax cables must be measured across the frequency of interest, and preamplifiers with the lowest noise figure available must be used. In most cases, FFT-based spectrum analyzers cannot be used because there is no provision for correction factor tables in these instruments. Thus, the measurements would be only relative and uncalibrated. When there is that provision, it will be for only one table, such as in Rohde & Schwarz (R&S) spectrum

APPENDIX A. BACKGROUND INFORMATION.

analyzers. In that case, antenna gain, coax loss, and preamplifier gain must be combined into one table. A standard spectrum analyzer, such as the Agilent E4407B, is used in this procedure, since the basic controls and functions are the same or similar to most other spectrum analyzers.

A.4 DETECTION MODE.

a. Modulated RF signals, rather than broadband noise, are the predominant form of interference; therefore, those techniques of measurement are used. The reason for establishing a baseline is for open-air EMC testing, local communications testing, or comparing interference levels between two or more locations. Open-air testing (OAT) would not be conducted near broadband noise sources such as high-voltage power lines, office buildings, or any other wideband noise source. How the signal is detected or demodulated is the biggest factor between broadband noise and modulated signal interference measurements. “Sampled detection” results in a more accurate noise measurement, but “peak detection” is more accurate for modulated sinusoid signals. Peak detection ensures that no sinusoid signal is missed, regardless of the ratio between RBW and bucket width. Peak detection also displays the highest peak regardless of bucket width. Thus, peak detection is used in this procedure.

For frequency, bucket width = span / (trace points – 1) Equation 7

b. CISPR 16 (Part 1-1) and American National Standards Institute (ANSI) C63.2[3] define and specify Quasipeak detection (QPD) for OAT. There is an “annoyance factor” to interference (how often the interference occurs). QPD is a weighted form of peak detection with a 1-ms charge time from 150 kilohertz (kHz) to 1 gigahertz (GHz) and a 160-ms to 550-ms discharge time, depending on frequency. QPD results in a higher displayed peak as the repetition rate of the interference increases. This method of detection eliminates the intermittent noise that would have little effect on a received signal. QPD is a standard form of detection for EMI receivers but not spectrum analyzers. On spectrum analyzers, it is an extra option that must be purchased. Averaging a fixed number of sweeps called “trace averaging” provides similar results. The peak amplitude of the interference will be higher if the interference occurs more often. This would indicate a larger “annoyance factor”. Like QPD, “trace averaging quantifies the “annoyance factor” of the interference. “Trace averaging” with 100 traces is used here instead of QPD.

c. The margin of error in a sample size is equal to $1/\sqrt{N}$ of the sample size. An average of 100 scans provides a margin of error of 10 percent or ±5 percent, which is adequate in this procedure. Comparing two areas and averaging 100 traces while measuring a 10-dB difference in noise floors would have an accuracy that could fluctuate by up to ±0.5 dB. This is somewhat less than what could be reasonably resolved on the spectrum analyzer screen.

APPENDIX A. BACKGROUND INFORMATION.

d. The results of these measurements might be used for OAT of EUT. The ambient background noise level would be measured first, then the EUT would be powered on and the scan would be conducted again. The second sweep would be a combination of the background ambient noise and the noise emitted from the EUT. The results of the ambient background sweep would then be subtracted from the results of the EUT and the background sweep to obtain just the noise emitted from the EUT. The most reliable results are obtained if trace averaging of 100 scans using peak detection is used. This is good for pre-compliance testing (see http://www.laplace.co.uk/ media/ download/ambient.pdf). If the units of measure for the two scans are in Log values like dBμV/m or dBm, the two scans must be converted to linear values before subtraction. The conversions are:

$$\text{Value in } \mu V = 10\text{^}(\text{value in dB}\mu V/20) \qquad \text{Equation 8}$$

e. Once converted to microvolts (μV), the two values can be subtracted and converted back to Log values or dBμV/m, as follows:

$$\text{Subtracted values in dB}\mu V/m = 20\times \text{LOG}(\text{larger value in } \mu V - \text{smaller value in } \mu V) \qquad \text{Equation 9}$$

f. Log values in dBm can be converted to dBμV/m by adding 107, then converted to linear values or μV using the preceding formula. The Log values may also be converted to watts and subtracted, then converted back to LOG values, as follows:

$$\text{Values in } \mu V = 10\text{^}((\text{value in dBm} + 107)/20) \qquad \text{Equation 10}$$

$$\text{Value in watts} = 10\text{^}((\text{value in dBm} - 30)/10 \qquad \text{Equation 11}$$

$$\text{Subtracted values in dBm} = 10\times \text{LOG (larger value in watts} - \text{smaller value in watts})+30 \qquad \text{Equation 12}$$

For example, subtract 30 dBm from 33 dBm. The answer is NOT 3 dBm; it is 30 dBm or 1 watt.

Power in watts = 10^((power in – 30)/10) = 10^((30-30)/10) = 1 watt

Power in watts = 10^((33-30)/10) = 2 watts

2 watts – 1 watt then converted back to dBm = 10×LOG(2-1)+30 = 30 dBm

A.5 DWELL TIME.

a. According to MIL-STD-461F for anechoic chamber testing, the dwell time for all frequencies is 15 ms. For OAT, CISPR 16 (Part 2-3) defines the minimum peak and QPD scan times shown in Table A-1. The dwell times using peak detection are shorter than those required for MIL-STD-461F.

APPENDIX A. BACKGROUND INFORMATION.

TABLE A-1. MINIMUM SCAN TIMES FOR THE CISPR BANDS FOR PEAK AND QUASI-PEAK DETECTORS

Frequency band		Scan time T_s for peak detection	Scan time T_s for quasi-peak detection
A	9 kHz – 150 kHz	14,1 s	2820 s = 47 min
B	0,15 MHz – 30 MHz	2,985 s	5 970 s = 99,5 min = 1 h 39 min
C/D	30 MHz – 1 000 MHz	0,97 s	19 400 s = 323,3 min = 5 h 23 min

b. From CISPR 16 (Part 2-3) (Table A-1), the scan time per frequency span for peak detection using a spectrum analyzer is specified by the following formula:

$$\text{Minimum sweep time} = (\text{k x Frequency span}) / \text{RBW}^2 \qquad \text{Equation 13}$$

Where “k” is a constant of proportionality related to the shape and rise time of the resolution filter. This constant assumes a value between 2 and 3 for synchronously tuned near Gaussian filters. For nearly rectangular stagger-tuned filters, “k” has a value between 10 and 15. Table A-1 uses a “k” equal to 10, which provides the longest minimum sweep time.

$$\textit{Band B minimum sweep time} = 10 \times 29{,}850\ \textit{MHz}/10\ \textit{kHz}^2 = 2.985\ \textit{S}$$

and

$$\textit{Band C/D minimum sweep time} = 10 \times 970\ \textit{MHz}/100\ \textit{kHz} = 0.97\ \textit{S}$$

c. As shown in Table A-1, the peak detection “trace averaging” scan method takes much less time than the quasi-peak detection method, while giving similar results. QPD is extremely time-consuming, making it impossible to do multiple scans from 2 MHz to 6 GHz in the course of a day.

A.6 <u>SCAN BANDS</u>.

a. MIL-STD-461F and CISPR 16 use similar scan parameter standards. These exact parameters need not be strictly adhered to if the frequencies of interest are different or narrower. For a narrower band of frequencies within the scan frequency ranges in Table A-2, the preceding formula would be used to determine the new time per scan.

APPENDIX A. BACKGROUND INFORMATION.

TABLE A-2. PARAMETERS FOR THE SCAN FREQUENCY RANGES

SCAN FREQUENCY RANGE	RBW	VBW = 3 x RBW	TIME PER SCAN
2–30 MHz	10 kHz	30 kHz	2.8 seconds
30–200 MHz	100 kHz	300 kHz	0.17 second
200 MHz – 1 GHz	100 kHz	300 kHz	0.8 second
1–2 GHz	1 MHz	3 MHz	0.01 second per GHz
2–6 GHz	1 MHz	3 MHz	0.04 second

b. The RBW and video bandwidth (VBW) from Table A-2 are adhered to for the scan frequency ranges containing the new frequencies of interest. The new scans would then correspond to the same specifications for the standard scan frequency ranges in the table.

A.7 ANTENNA HEIGHT.

The antenna height based on CISPR 16 (Part 2-3) may vary between 1 and 6 meters above the ground. It may also be positioned to maximize signal strength readings. The antenna must be high enough that its lowest point is at least 25 centimeters (cm) above the ground.

A.8 ANTENNA POLARIZATION.

Most signal sources are radiated or reflected from vertical structures. For this reason, vertical polarized or vertical and horizontal combination antennas are used. When vertical polarization is used it is much easier to make measurements in an omnidirectional pattern. Once a signal is reflected, its polarization may change and become a combination of vertical and horizontal polarization. To compare and get fair results in two or more locations, the same type of antenna must be used for all of the areas under test. In the examples here, an omnidirectional active monopole vertical polarized antenna is used for the 2-MHz to 30-MHz scan. From 30 MHz to 6 GHz, an omnidirectional combination vertical and horizontal polarized antenna is used. Both antennas have antenna correction factor tables. As stated in the preceding paragraph A.3.a, because far field measurements are being made with units of measure in dBm for power, the antenna factors are converted to gain in dBd. Gain in dBd is gain compared to a dipole antenna as opposed to gain in dBi compared to an isotropic antenna or a point source. Point source antennas do not exist in the real world, but dipole antennas do exist. The gain of an antenna expressed in dBi would have 2.15 dB more gain than if the same antenna gain was expressed in dBd. Real-world measurements are expected; therefore, antenna gain in dBd is used.

APPENDIX A. BACKGROUND INFORMATION.

A.9 REDUCING VOLTAGE STANDING WAVE RATIO (VSWR).

a. Most military communication radios operate between 2 MHz and 18 GHz. In the examples here, 2 MHz - 6 GHz is used. MIL-STD-461F and CISPR 16 establish testing bandwidths and parameters. Per CISPR 16 (Part 1-1) for measurements up to 1 GHz, and with the input attenuator set to “0dB” for maximum sensitivity, the VSWR is required to be 2:1 or less. For measurements above 1 GHz, the VSWR is required to be 3:1 or less. It is not enough that one end of the coax is terminated into its characteristic impedance; both ends need to be properly terminated. Otherwise, the measured signal strength would depend on the length of the coax cable between the antenna output and the input of the spectrum analyzer, as illustrated by the red trend line in Figures A-1 and A-2.

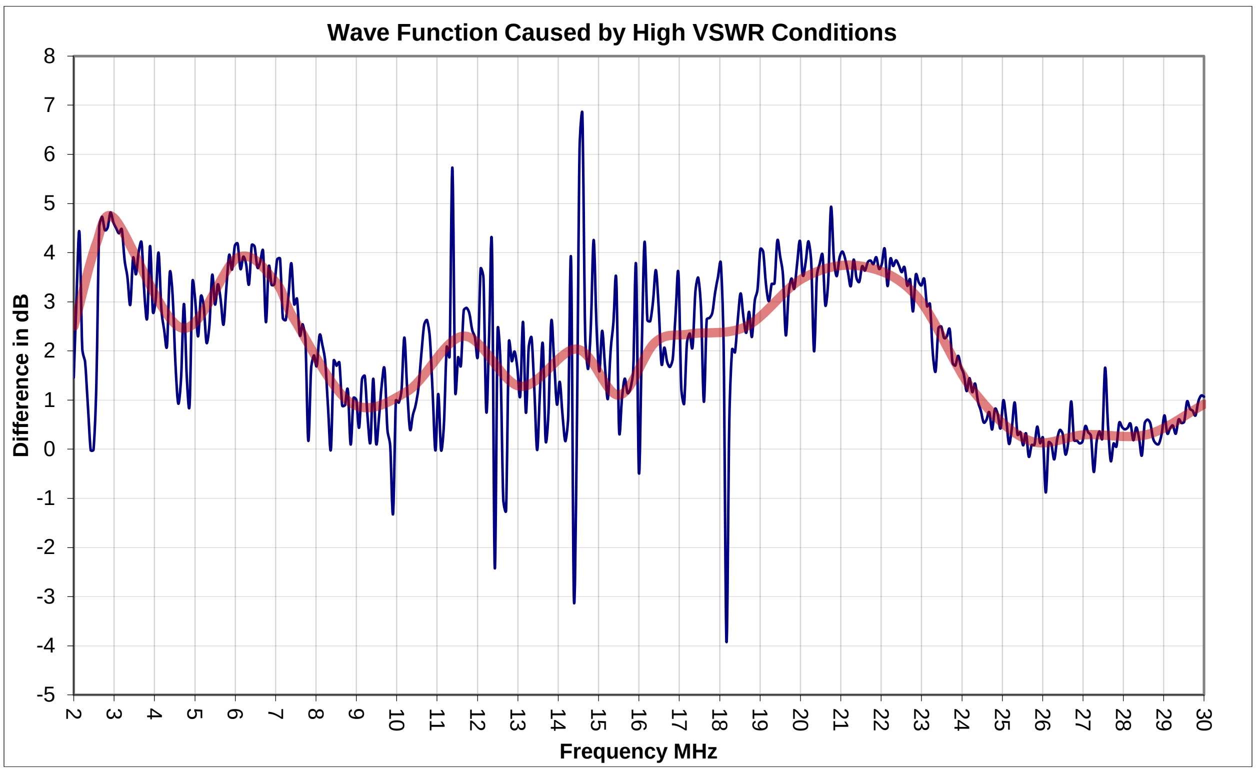

Figure A-1. Blue waveform subtracted from red waveform in Figure A-4.

APPENDIX A. BACKGROUND INFORMATION.

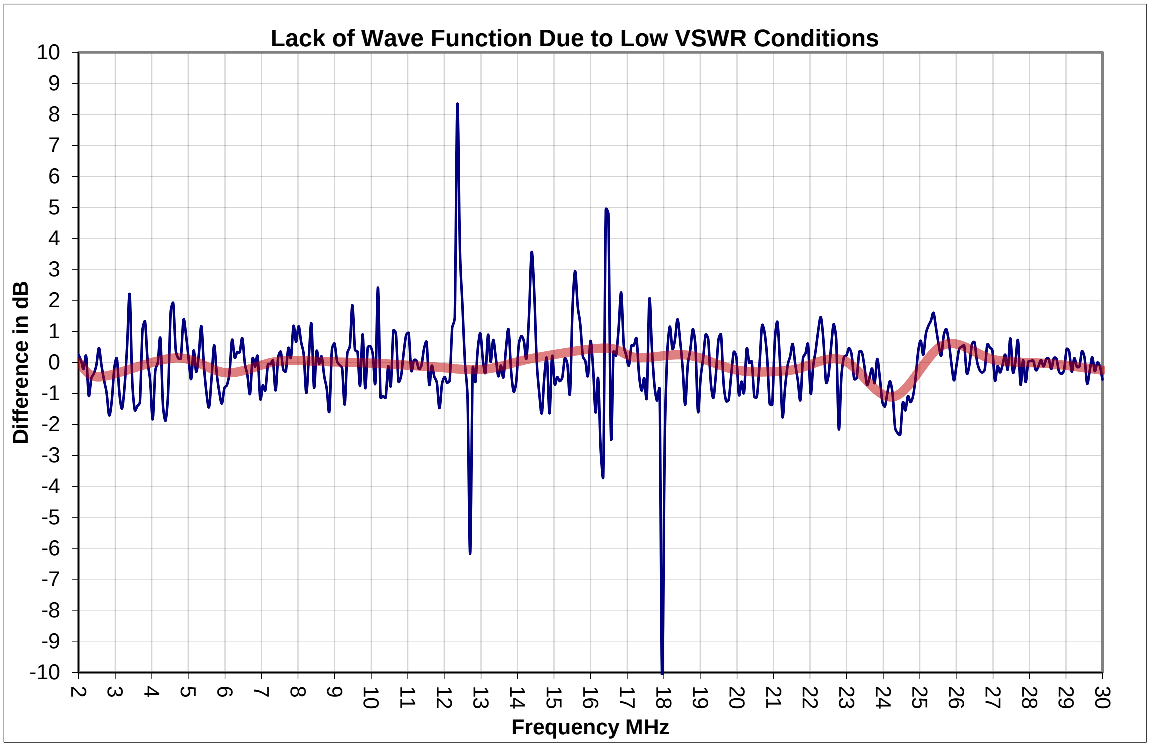

Figure A-2. Blue waveform subtracted from red waveform in Figure A-4.

b. Figure A-3 shows the different ambient signal levels with traces for both 0-dB and 5-dB input attenuation selected. The red trace in Figure A-3 shows ambient signal levels with 0 dB of input attenuation on the spectrum analyzer, and the blue trace shows the same signals with 5 dB of input attenuation. Both are with the coax connected directly to the antenna output. As can be seen, the levels displayed are different, even if the inputs are nearly the same. It is critical to record instrument settings.

APPENDIX A. BACKGROUND INFORMATION.

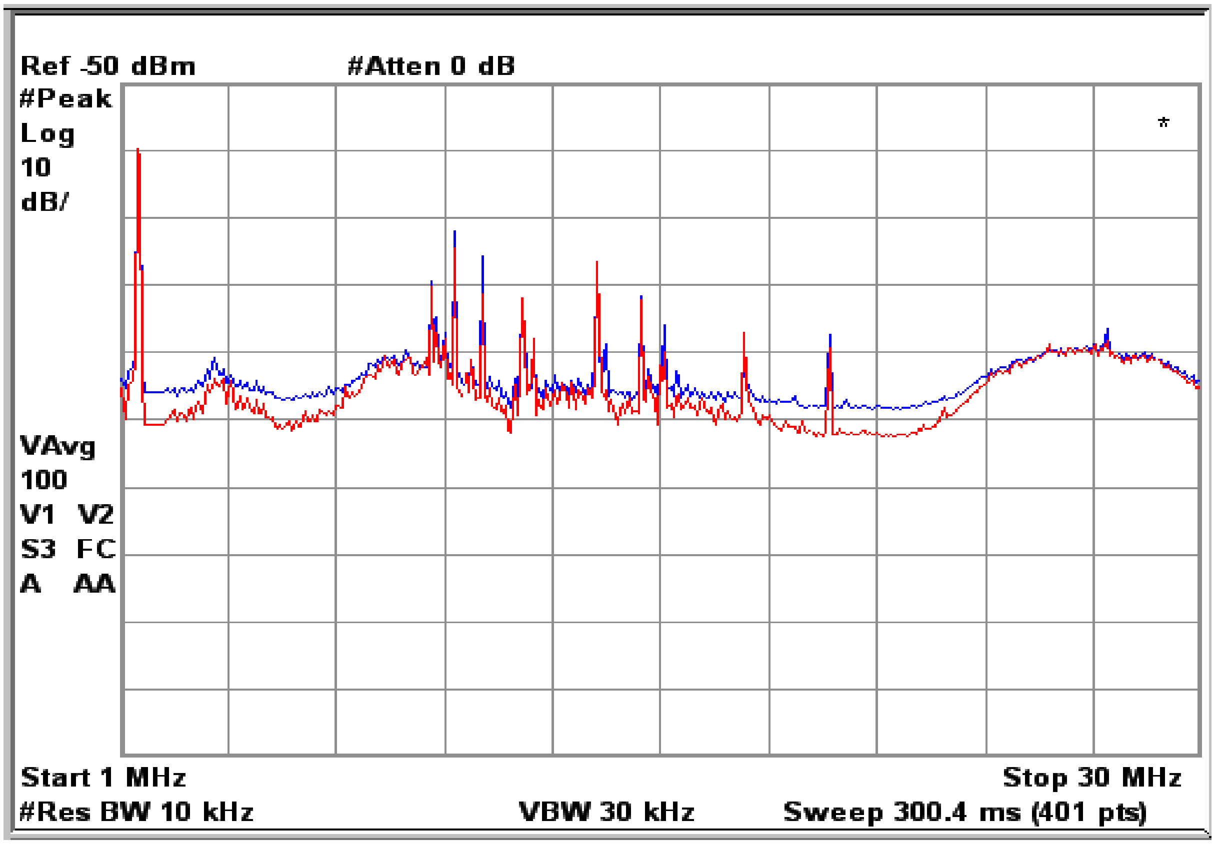

Figure A-3. Input attenuation effects on spectrum analyzer display.

c. The circuitry at the input of the spectrum analyzer comprises an attenuator, matching network, and input filter that couples the signal to the first mixer. These circuit elements are required to match the coax to the first stage of the spectrum analyzer across its entire operating frequency and is a compromise at best. With zero attenuation used, the match is good but not perfect. A better match can be obtained by using the input attenuator because it uses resistive elements instead of inductive and capacitive elements. Inductive and capacitive components are not purely inductive and capacitive but a mixture of both, causing slight mismatches at different frequencies. The resistors making up the input attenuator have little inductive or capacitive elements because they are small in size compared to the input frequency wavelengths. The input attenuator is designed to limit the input signal amplitude and match the impedance of the coax across the instrument’s entire operating frequency, creating a low VSWR. The cost of the lower VSWR is that any attenuation at the input and before the first mixer directly adds to the noise figure of the instrument. The noise figure increases by 5 dB if 5 dB of attenuation is added. This can be seen on the display of the spectrum analyzer as an increase in DANL by the same amount as the increase in input attenuation

APPENDIX A. BACKGROUND INFORMATION.

d. The output impedance of broadband antennas changes with frequency. This can be controlled to some extent by careful antenna design and matching networks, but the result is never perfect. When both ends of a length of coax cable are not terminated by the same impedance as the characteristic impedance of the coax, standing waves are created. The worse the mismatch, the higher the VSWR. The VSWR is worse when both ends of the coax are mismatched rather than just one end. This is seen as a wave function when the two signal levels are compared as the frequency changes. This is noticeable in Figure A-3 but is more evident when one of the scans is subtracted from the other. Figure A-1 displays the blue waveform subtracted from the red waveform in Figure A-3 and shows a VSWR wave function (red trend line) caused by mismatches at both ends of the coax, from the antenna to the spectrum analyzer. The signal amplitudes fluctuate, and the regular wave pattern in those fluctuations is shown by the red trend line in Figure A-1.

e. Mounting a preamplifier on the output port of the antenna to drive the coax solves the coax mismatch problem, protects the input stage of the spectrum analyzer, and lowers the noise figure of the entire system. Most often, the input and output VSWR of preamplifiers are specified to be 2:1 or lower, about the same as the input of spectrum analyzers. To prevent damage, it is recommended not to connect an antenna directly to the input of a spectrum analyzer without using input attenuation. It is much less expensive to replace a preamplifier than the front end of a spectrum analyzer. Also, the addition of a preamplifier lowers the noise figure and the DANL.

f. In Figure A-4, both the blue and the red waveforms overlap about evenly with no obvious fluctuating pattern visible. When one waveform is subtracted from the other, there should be little or no regular pattern noticeable in the results, as shown by the red line trend in Figure A-2.

g. Figure A-2 shows that there is, in fact, very little visible pattern (red trend line) and just random fluctuations in the two signal scans. This indicates a good impedance match at both ends of the coax. In this case, if there was a change in the length of the coax, there would be no change in the amplitude of the signal at the input of the spectrum analyzer as the frequency changes. Likewise, if there is no coax between the output of the antenna and the input of the preamplifier, there are no problems with standing waves in a changing length of coax. The result is that keeping the VSWR low makes the measurements more accurate and reliable. As shown in Figure A-1, connecting the coax directly to the antenna adds a ±4-dB error to the internal error of the spectrum analyzer. If a preamplifier is not available or the internal preamplifier is used, the input attenuator should be set to a minimum of 5 dB. If a preamplifier is used at the antenna output to drive the coax, the internal attenuator can be set to 0 dB.

APPENDIX A. BACKGROUND INFORMATION.

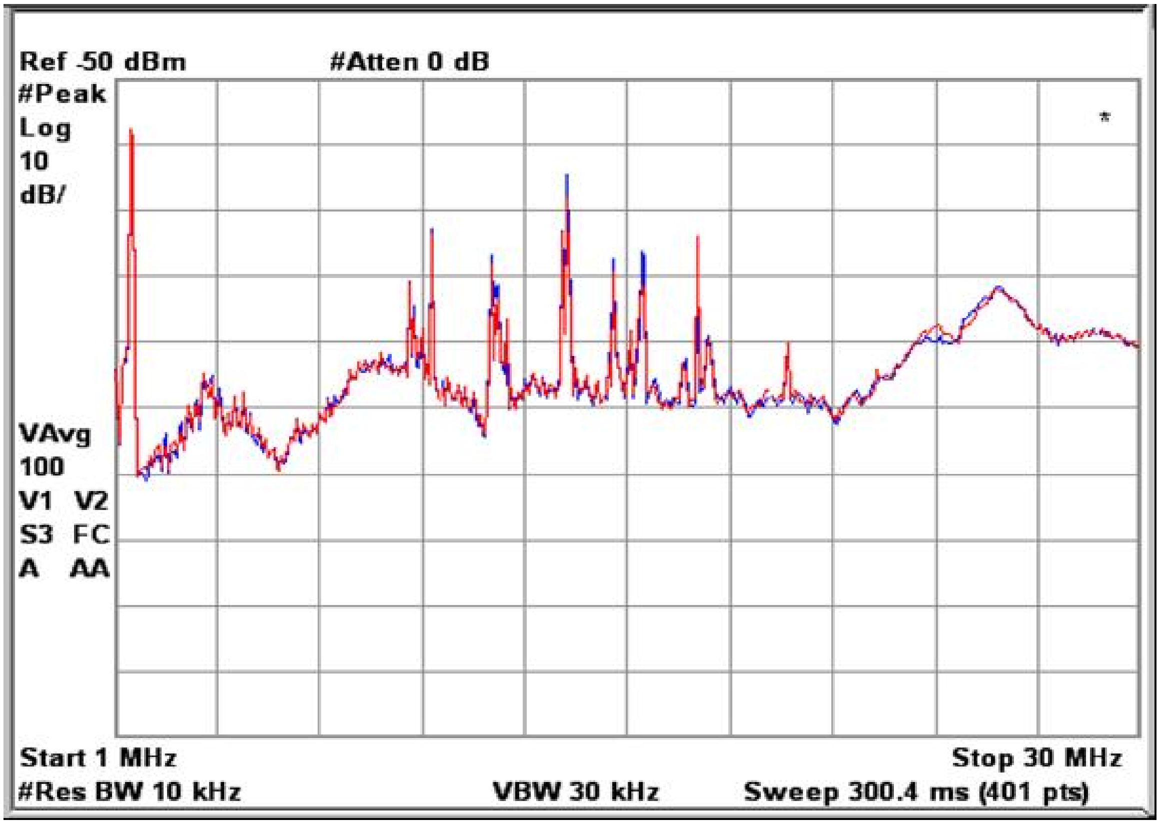

Figure A-4. Preamplifier correction of coax impedance mismatch on spectrum analyzer display.

A.10 <u>DANL OF THE SPECTRUM ANALYZER</u>.

a. It is important that the system sensitivity, dictated by the displayed average noise level of the instrument, is known. The DANL of any spectrum analyzer can be experimentally determined by terminating the input port with its characteristic impedance [50 ohms (Ω) used here], then observing the screen. This level is the spectrum analyzer's own noise floor. Any signals below this level cannot be seen. Also important is not using an RBW any wider than the signal modulation in the band of frequencies being measured. The DANL will increase by approximately 10 dB for every order of magnitude increase in RBW.

b. Figure A-5 shows that decreasing the RBW by a factor of 10 reduces the DANL by 10 dB. In the blue trace, the RBW was set to 1 MHz, and in the red trace, the RBW was set to 100 kHz. Both scans have the same peak waveform because the signal was unmodulated and continuous wave (CW). A single unmodulated CW carrier would have the same peak amplitude regardless of the RBW.

APPENDIX A. BACKGROUND INFORMATION.

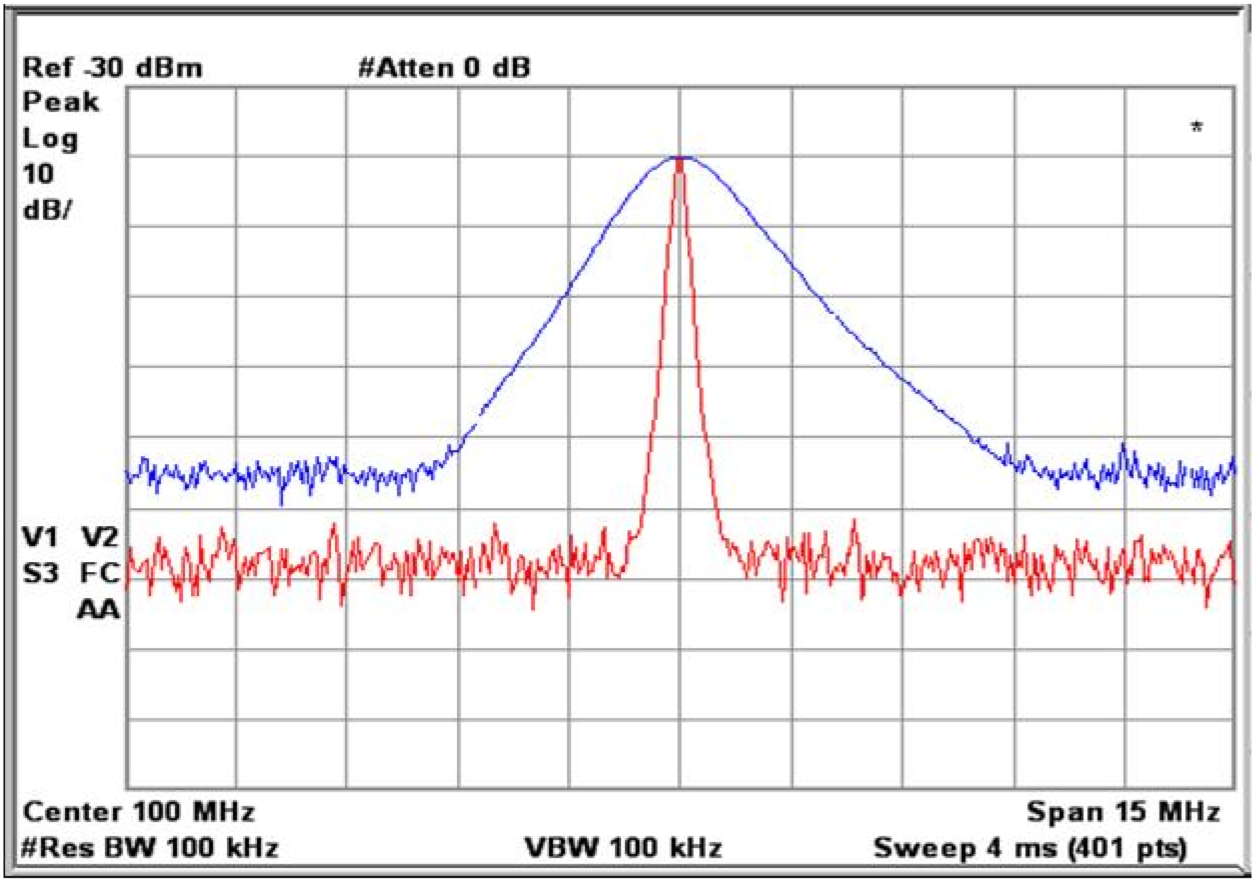

Figure A-5. Reducing the RBW by a factor of 10 reduces the DANL by 10 dB and increases resolution.

c. The RBW should not be any wider than the bandwidth of the expected signals being monitored. If the widest modulated signals in the scan are 25 kHz wide, then an RBW of 30 kHz should be used since that is the next widest RBW available. The VBW in most spectrum analyzers automatically defaults to the RBW, so both end up being the same. This causes power in the side slopes of the displayed signal to not be included in the measurement, thus reducing the peak displayed power of that signal. This is because the side slopes of all filters are not perfectly vertical but slope off to the sides at an angle. When measuring modulated signals, it is recommended that a VBW three times wider than the RBW be used.

APPENDIX A. BACKGROUND INFORMATION.

d. On spectrum analyzers set to detect Max Peak, the RBW can be set narrower than the total span divided by the number of display points called the "bucket width," without loss of signal. When set to detect Max Peak, the signal with the most amplitude within that bucket is measured. This is not true with EMI receivers used in anechoic chambers for radiated emissions (RE) testing, such as RE102. When testing in that environment, the RBW should be somewhat wider than the total span divided by the number of points, as specified in MIL-STD-461F.

For frequency, bucket width = span / (trace points – 1)

For time, bucket width = sweep time / (trace points – 1)

e. The DANL observed at 10 kHz RBW would be 10 dB higher at 100 kHz RBW. The reverse is also true. For every decrease in RBW by a factor of 10, there will be a decrease in DANL by 10 dB. For other RBW changes, the difference would be:

$$\text{New DANL} = 10\times\log\left(1^{st}\ \text{RBW}/2^{nd}\ \text{RBW}\right) \qquad \text{Equation 14}$$

For example, changing the RBW from 1 MHz to 3 MHz increases the DANL and would be:

Increase in DANL = 10×log (3 MHz/1 MHz) = 4.77 dB

f. If the noise figure of the spectrum analyzer is known, the DANL at any other RBW can be predicted, as that noise figure is independent of the RBW. That noise figure can then be used to predict the DANL at any other RBW. An Agilent E4407B is used as an example to determine the noise figure experimentally.

g. The settings in Table A-3 are used for reading the DANL directly from the screen with no preamplifier. Note that the VBW is set to three times the RBW; this ensures that no power is lost in the waveform skirts of the video filter. This is the recommended practice for all measurements. The measurement span is 1 MHz; therefore, the bucket width is span/points, which is 1 MHz/401 = 2.494 kHz (much narrower than the RBW of 10 kHz) and does not cause a measurement accuracy problem. To reduce the display noise, trace averaging is used. The sweep time should be left set to auto.

APPENDIX A. BACKGROUND INFORMATION.

TABLE A-3. SPECTRUM ANALYZER SETTINGS, NO PREAMPLIFIER

Ref Level	-50 dBm
Attenuation	0 dB
Internal Preamplifier	Off
Start Frequency	999 MHz
Stop Frequency	1 GHz
RBW	100 kHz
VBW	300 kHz
Sweep Time	Auto
Video Average	100
Max Hold	Off
External Gain	0 dB

h. The level shown in Figure A-6 is the noise floor of the spectrum analyzer for an RBW of 100 kHz, -97.58 dBm. The noise figure of the instrument is:

$$\text{Noise figure} = \text{DANL} - 10\times\log(\text{RBW}) + 174\ \text{dBm} = -97.6 - 40 + 174 = 26.4\ \text{dB} \qquad \text{Equation 15}$$

i. The noise figure is independent of the RBW and is used to predict the DANL at any other RBW. As stated in the preceding paragraph A.10.f, any attenuation - whether preset in the front end of the spectrum analyzer or in the coax cable connected to an antenna - directly adds to the noise figure of the system. The DANL will increase by the amount of internal attenuation used.

j. The blue trace shown in Figure A-7 was made with the internal attenuator set to zero. The red trace was made with the internal attenuator set to 10 dB. The additional 10 dB of attenuation causes the DANL to increase by 10 dB. When an external preamplifier is used, it protects the front end of the spectrum analyzer. It is then safe to reduce the internal attenuation to zero, thus lowering the DANL by the amount of attenuation removed. The external preamplifier must also be compensated for by turning on the gain correction table in the spectrum analyzer. The correction table is composed of the gain of the preamplifier measured for the frequency band of interest.

APPENDIX A. BACKGROUND INFORMATION.

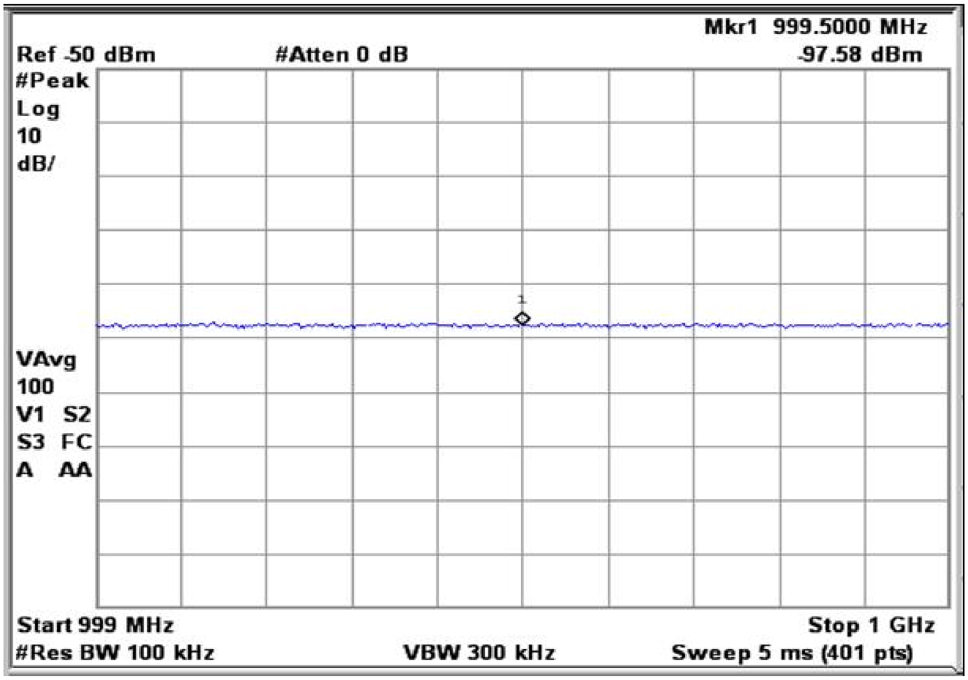

Figure A-6. With the input terminated, the DANL is -97.58 dBm.

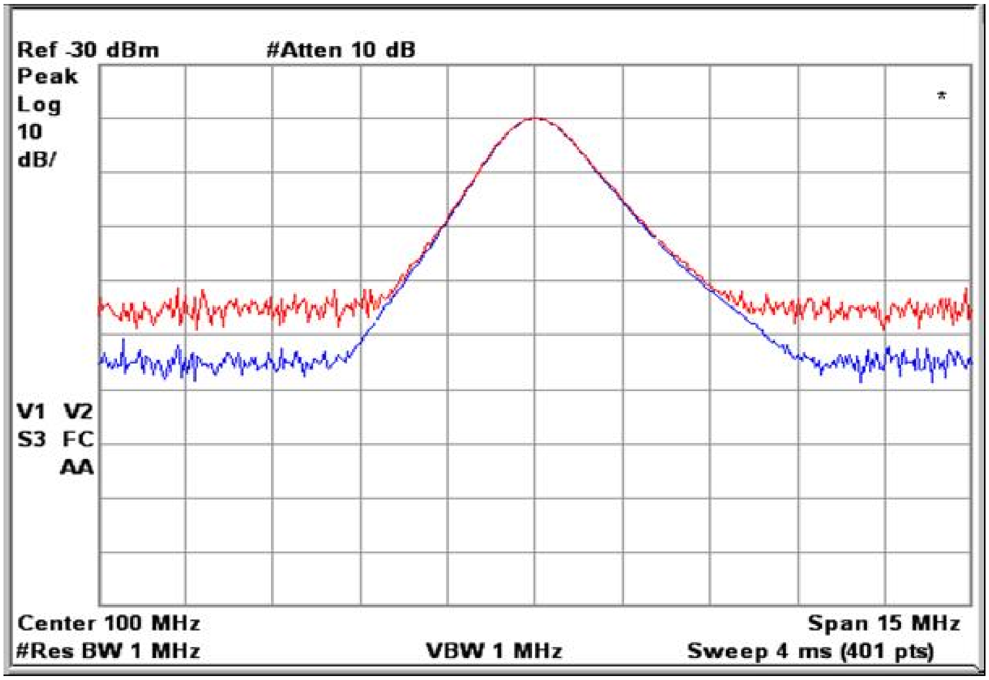

Figure A-7. Increasing the input attenuator increases the DANL,
while the peak of the CW signal remains the same.

APPENDIX A. BACKGROUND INFORMATION.

k. It cannot be overstated that once the signal of interest disappears into the noise, it cannot be recovered. As explained in the preceding paragraph A.9, this is why it is important to add a preamplifier directly to the antenna output connector to drive the coax connected to the input of the spectrum analyzer. The preamplifier's output impedance is more likely to be closer to 50 Ω across the spectrum being measured than the output of the antenna. This provides a lower VSWR than would be measured at the output of the antenna. This, in turn, prevents the length of the coax from controlling the input signal level at the front end of the spectrum analyzer. The preamplifier should have enough gain to overcome the loss of the coax. It then establishes the noise figure of the system instead of the attenuation of the coax cable added to the noise figure of the spectrum analyzer. A small signal preamplifier with the lowest noise figure available should be used. The tradeoff is that gain beyond the loss of the coax decreases the dynamic range of the system. If an external preamplifier is used, the preamplifier in the spectrum analyzer should not be used. The internal preamplifier can be easily overdriven, creating spurious signals.

l. The blue trace shown in Figure A-8 is a normal Max Hold trace using a 28-dB gain preamplifier at the antenna. This is a true representation of the spectrum. The red trace shows what happens when the internal preamplifier is used in conjunction with an external preamplifier. The internal preamplifier is being overdriven, causing many spurious signals. This is the result of numerous signals in the band of interest, along with signals outside the band of interest all heterodyning together.

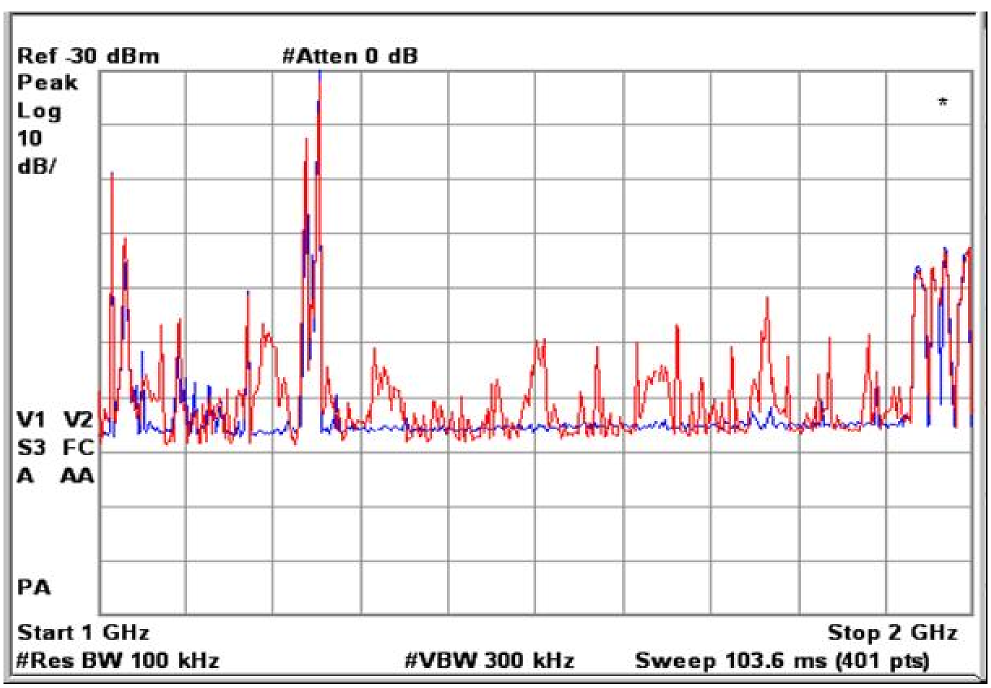

Figure A-8. Spurious signals (in red) caused by using both an external and an internal preamplifier.

APPENDIX A. BACKGROUND INFORMATION.

m. Once the noise figure of the spectrum analyzer is known, along with the preamplifier specifications, the expected DANL at the desired RBW can be calculated. The preamplifier used in the following formula is a Mini-Circuits ZFL-1000LN+ with a noise figure of 3.3 dB, a gain of 21.8 dB, and a frequency response from 0.1 to 1000 MHz. The RBW is set to 100 kHz, but any other RBW available could be used. In calculating the combined noise figure of the preamplifier connected to the input of the spectrum analyzer, linear instead of decibel values must be used. To determine the linear noise figure and gain of the preamplifier plus spectrum analyzer combination, the anti-log of the decibel values of the noise and gain factors are calculated. This is done by using the following formula:

$$\text{Linear noise or gain factors} = 10\text{\^{}}\,(\text{noise figure or gain in dB}/10) \qquad \text{Equation 16}$$

$$\textit{LNA noise factor} = 10\text{\^{}}\,(3.3/10) = 2.14$$

$$\textit{LNA gain factor} = 10\text{\^{}}\,(21.8/10) = 151.36$$

$$\textit{Spectrum analyzer noise factor} = 10\text{\^{}}\,(26.4/10) = 436.52$$

The spectrum analyzer displays the true amplitude of the signal being measured so its gain is 1.

$$\text{Total system noise factor} = \frac{\text{LNA noise factor + (spectrum analyzer noise factor - 1)}}{\text{LNA gain factor}} \qquad \text{Equation 17}$$

$$\textit{Total system noise factor} = 2.14 + (436.52 - 1)\,/151.36 = 5.02$$

$$\text{Total system noise figure} = 10\times\log\,(\text{total system noise factor}) = 10\times\log\,(5.02) = 7.0\text{ dB} \qquad \text{Equation 18}$$

$$\textit{Expected DANL} = \textit{System noise figure} + 10\times\log\,(RBW) - 174 = 7.0 + 40 - 174 = -117.0\ dBm$$

n. The settings in Table A-4 are used to determine the actual DANL of the system using the preamplifier.

APPENDIX A. BACKGROUND INFORMATION.

TABLE A-4. SPECTRUM ANALYZER SETTINGS, WITH PREAMPLIFIER

Ref Level	-50 dBm
Attenuation	0 dB
Internal Preamplifier	Off
Start Frequency	999 MHz
Stop Frequency	1 GHz
RBW	100 kHz
VBW	300 kHz
Sweep Time	Auto
Video Average	100
Max Hold	Off
External Gain	21.8 dB

o. The expected DANL calculated in Figure A-9 was -117.0 dB, and the measured DANL was -117.3 dB, for a difference of 0.3 dB, which is well within a margin of error of ±1 dB for the Agilent E4407B spectrum analyzer. With the known noise figure of 26.4 dB, the expected DANL can now be determined for any other RBW.

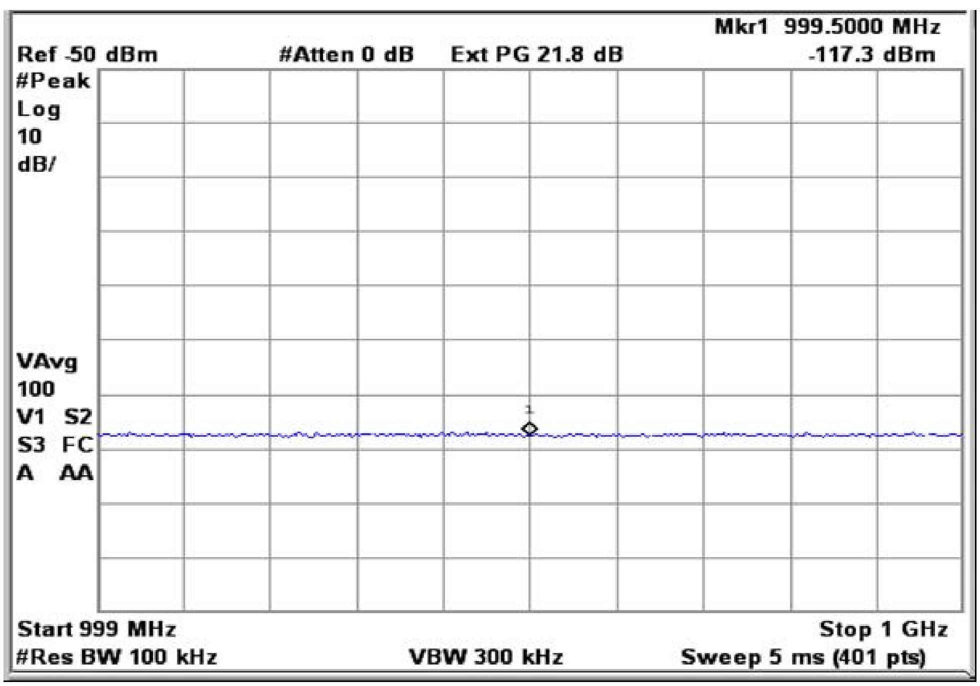

Figure A-9. DANL of -117.3 dBm using an added preamplifier.

APPENDIX A. BACKGROUND INFORMATION.

p. If measurements were taken at the maximum operating frequency of the preamplifier (1 GHz), the performance would be at the lowest for worst-case conditions.

A.11 SENSITIVITY AND REFERENCE LEVEL.

a. A measured signal equal in amplitude to the DANL of the spectrum analyzer will appear approximately 2.2 dB above the DANL of the instrument. If the measurement is made at a reference level of -20 dBm, all that can be seen is a bump in the DANL. The DANL can be reduced by several dB when the reference level is lowered; this method allows the measurement of signals near the limit of the instrument. Figure A-10 provides an example.

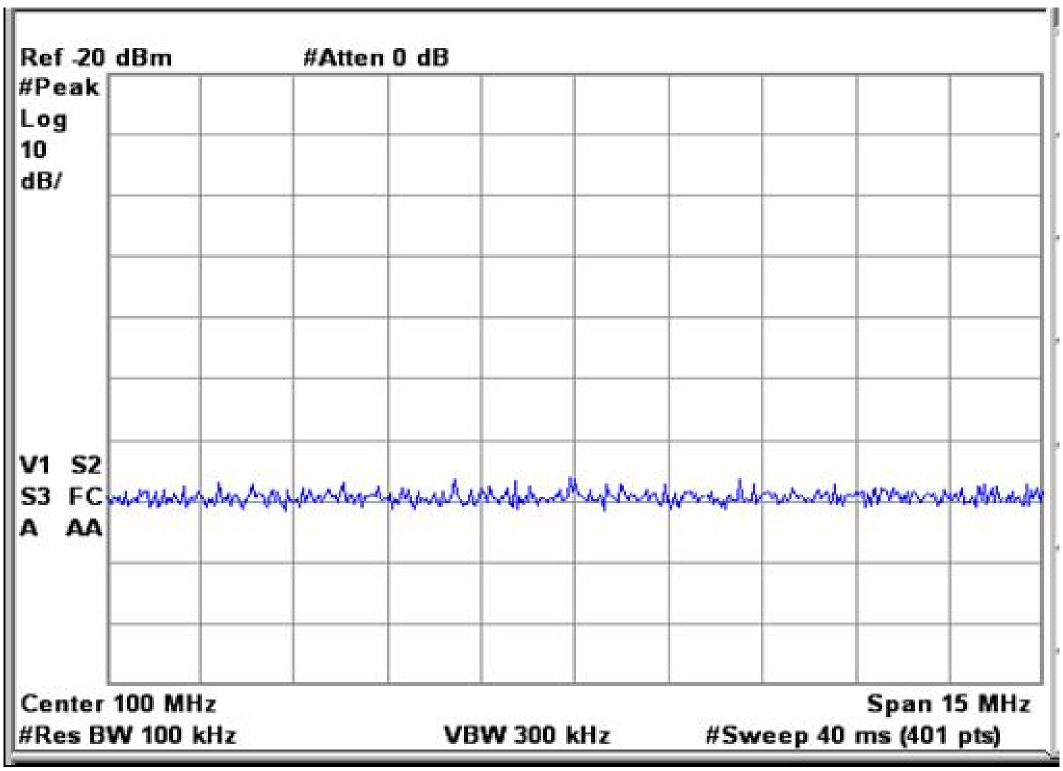

Figure A-10. Signal equal in amplitude to the DANL.

b. Figure A-10 shows that the signal at 100 MHz in the center of the display is equal to the DANL (this is difficult to see). Trace averaging (Figure A-11) will make it more noticeable.

APPENDIX A. BACKGROUND INFORMATION.

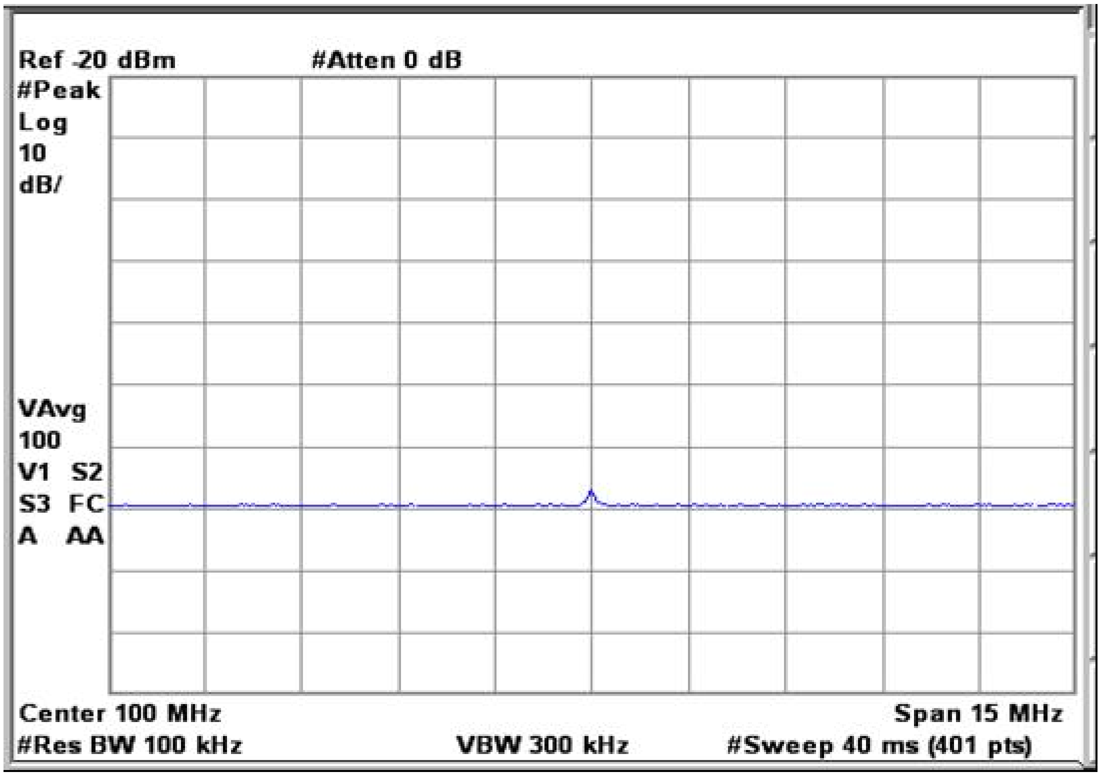

Figure A-11. Trace averaging enables the signal to be seen with the DANL at -89.4 dBm.

c. The 100-MHz signal at the same amplitude as the DANL is now observable approximately 2.2 dB above the noise. This is considered the minimum measureable signal. The amplitude of the signal and the noise are both -89.4 dBm. The displayed amplitude of the signal is 86.8 dBm, 2.6 dB above the noise for an error of 2.6 dB. Reducing the reference level by 30 dB (Figure A-12) will increase the sensitivity and lower the DANL, making the signal more visible.

APPENDIX A. BACKGROUND INFORMATION.

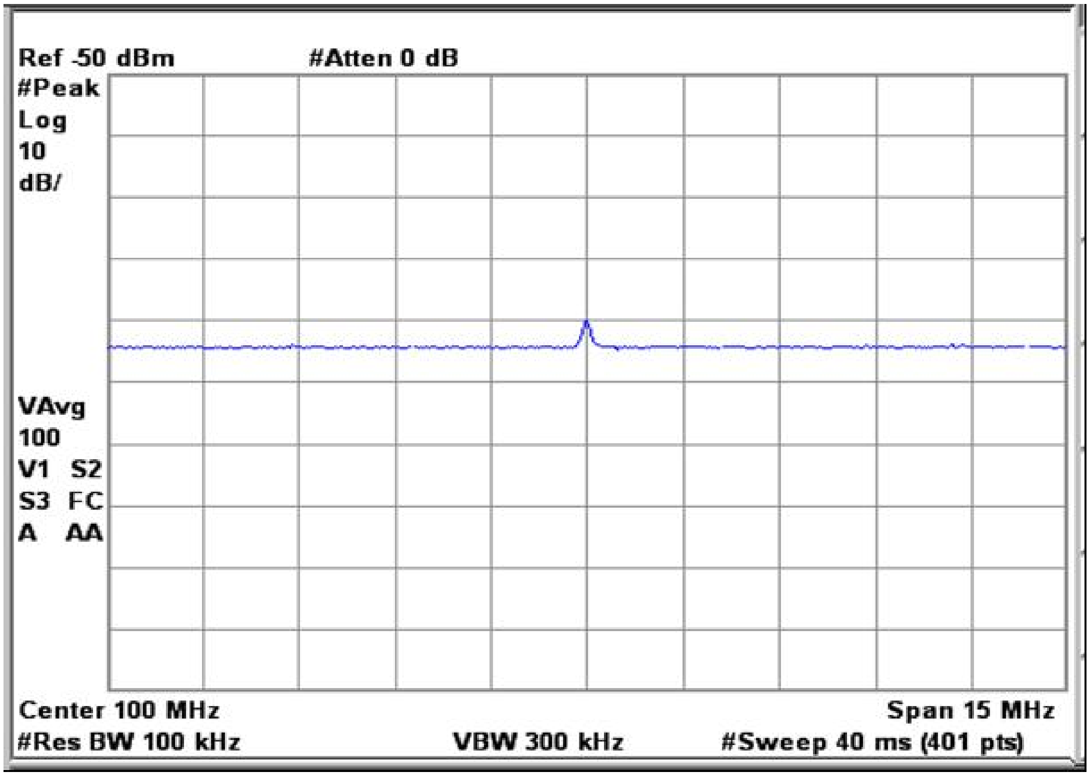

Figure A-12. Reference level reduced by 30 dB to -50 dBm lowers the DANL.

d. The peak of the signal is indicated at -89.9 dBm, which is within 0.5 dB of the actual amplitude of the signal at -89.4 dBm. The error is now only 0.5 dB. The DANL at a reference level of -20 dBm is -89.4 dBm, and the DANL at a reference level of -50 dBm is -94.4 dBm, for an improvement of 5.0 dB. This reduction in DANL and improvement in sensitivity did not require any additional equipment or time.

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APPENDIX B. ABBREVIATIONS.

µV	microvolt
Ω	ohm
AF	antenna factor
ANSI	American National Standards Institute
AR	Army Regulation
AST	ATEC Systems Team
ATEC	U.S. Army Test and Evaluation Command
CISPR	Comité International Spécial des Perturbations Radioélectriques
cm	centimeter
CW	continuous wave
DA	Department of the Army
DANL	displayed average noise level
dB	decibel
dBµV/m	decibels referenced to 1 microvolt per meter
dBd	decibels referenced to a dipole antenna
dBi	decibels referenced to an isotropic antenna
dBm	power ratio, in decibels, of the measured power referenced to 1 milliwatt
dB/m	decibels per meter
dBw	decibels referenced to 1 watt
dc	direct current
DOD	Department of Defense
EMC	electromagnetic compatibility
EMI	electromagnetic interference
EPG	U.S. Army Electronic Proving Ground
EUT	equipment under test
FFT	fast Fourier transform
GHz	gigahertz
Hz	hertz
K	Kelvin
kHz	kilohertz
MHz	megahertz
MIL-STD	Military Standard
ms	millisecond

APPENDIX B. ABBREVIATIONS.

OAT	open air testing
Pam	Pamphlet
QPD	Quasipeak detection
R&S	Rohde & Schwartz
RBW	resolution bandwidth
RE	radiated emissions
RF	radio frequency
RFA	radio frequency authorization (spectrum use approval)
SUT	system under test
TOP	Test Operations Procedure
VBW	video bandwidth
VSWR	voltage standing wave ratio

APPENDIX C. REFERENCES.

1. MIL-STD-461F, Department of Defense Interface Standard, Requirements for the Control of Electromagnetic Interference Characteristics of Subsystems and Equipment, 10 December 2007.

2. CISPR 16, *"Comité International Spécial des Perturbations Radioélectriques"* (International Special Committee on Radio Interference) Measuring Apparatus, 2007.

3. ANSI C63.2, American National Standard for Electromagnetic Noise and Field Strength Instrumentation, 10 Hz - 40 GHz Specifications, 15 December 2009.

For information only (related publications).

a. Army Regulation (AR) 73-1, Test and Evaluation, Test and Evaluation Policy, 1 August 2006.

b. Department of the Army (DA) Pamphlet (Pam) 73-1, Test and Evaluation, Test and Evaluation in Support of System Acquisition, 30 May 2003.

c. ATEC Regulation 73-1, Test and Evaluation, System Test and Evaluation Policy, 22 March 2013.

d. ATEC Pamphlet 73-1, Test and Evaluation, Volume I - System Test and Evaluation Procedures, 9 July 2013.

e. AR 5-12, Management, Army Use of the Electromagnetic Spectrum, 15 February 2013.

f. AR 25-52, Information Management: Records Management, Authorized Abbreviations, Brevity Codes, and Acronyms, 21 February 2014.

g. "Spectrum Analyzer Basics", Agilent/Keysight Application Note 150, http://cp.literature.agilent.com/litweb/pdf/5952-0292.pdf.

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APPENDIX D. APPROVAL AUTHORITY.

CSTE-TM 16 February 2016

MEMORANDUM FOR

Commanders, All Test Centers
Technical Directors, All Test Centers
Directors, U.S. Army Evaluation Center
Commander, U.S. Army Operational Test Command

SUBJECT: Test Operations Procedure (TOP) 06-2-595 Characterization of an Outdoor Ambient Radio Frequency Environment, Approved for Publication

1. TOP 06-2-595 Characterization of an Outdoor Ambient Radio Frequency Environment, has been reviewed by the U.S. Army Test and Evaluation Command (ATEC) Test Centers, the U.S. Army Operational Test Command, and the U.S. Army Evaluation Center. All comments received during the formal coordination period have been adjudicated by the preparing agency. The scope of the document is as follows:

This TOP provides procedures to characterize an ambient radio frequency (RF) environment (sometimes referred to as "radio frequency noise") prior to testing of a specific system under test (SUT). With this characterization, locations can be selected to avoid RF interference, providing optimal test conditions for the given SUT. This procedure requires calibrated equipment to generate accurate results, allowing for comparisons between test locations, and selection of the best location for a given test.

2. This document is approved for publication and will be posted to the Reference Library of the ATEC Vision Digital Library System (VDLS). The VDLS website can be accessed at https://vdls.atc.army.mil/.

3. Comments, suggestions, or questions on this document should be addressed to U.S. Army Test and Evaluation Command (CSTE-TM), 2202 Aberdeen Boulevard-Third Floor, Aberdeen Proving Ground, MD 21005-5001; or e-mailed to usarmy.apg.atec.mbx.atec-standards@mail.mil.

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Forward comments, recommended changes, or any pertinent data which may be of use in improving this publication to the following address: Range Infrastructure Division (CSTE-TM), U.S. Army Test and Evaluation Command, 2202 Aberdeen Boulevard, Aberdeen Proving Ground, Maryland 21005-5001. Technical information may be obtained from the preparing activity: U.S. Army Electronics Proving Ground, 2000 Arizona Street, Fort Huachuca, Arizona, 85613-7063. Additional copies can be requested through the following website: http://www.atec.army.mil/publications/topsindex.aspx, or through the Defense Technical Information Center, 8725 John J. Kingman Rd., STE 0944, Fort Belvoir, VA 22060-6218. This document is identified by the accession number (AD No.) printed on the first page.